63-3-4

ELECTRONICS TEST AGENCY
U.S. ARMY TEST AND EVALUATION COMMAND

ETA 10

FINAL REPORT

AUGUST 1962

ANNEX F

TO FINAL REPORT OF

ENGINEERING EVALUATION OF U.S. ARMY SIGNAL CORPS AUTOMATIC ELECTRONIC TELEPHONE SWITCHING AND AUXILLARY EQUIPMENTS

U.S. ARMY ELECTRONIC PROVING GROUND
FORT HUACHUCA, ARIZONA

ANNEX F

MELPAR REPORT

FINAL REPORT

ENGINEERING EVALUATION OF U.S. ARMY SIGNAL CORPS AUTOMATIC ELECTRONIC TELEPHONE SWITCHING AND AUXILIARY EQUIPMENTS

VOLUME III

TEST RESULTS

SIGNAL CORPS CONTRACT NO. DA-36-039-sc-80543
SIGNAL CORPS TECHNICAL REQUIREMENTS NO. SIG COMM 4-59
(AS AMENDED)
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Prepared For

U.S. ARMY ELECTRONIC PROVING GROUND
FORT HUACHUCA, ARIZONA

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VOLUME III

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ANNEX B

TEST RESULTS

1.0 INTRODUCTION

1.1 This annex presents the complete test results obtained during the engineering test and evaluation of the U. S. Army Signal Corps automatic electronic telephone switching and auxiliary equipments.

1.2 The theory of test and detailed test plans and procedures for the entire evaluation program are presented in Volume II, Annex A, of this report.

1.3 The presentation of the test results is in tabular and graphical form. Where techniques of statistical inference are employed, the most probable arithmetic mean is plotted and a range is shown which is the limit of excursion of sample means with a 95 per cent confidence level. In those cases where all lines are tested, where statistical inferences are not made, or where the range of excursion of the sample means is too small to conveniently plot, the arithmetic mean only is plotted.

1.4 Section 2.0 presents the operational and technical descriptions of the individual equipments tested followed by the detailed basic transmission test results. These results are secured from extensively testing one unit of each type of electronic switching central (presented graphically), and from testing on a limited basis succeeding units (presented in tabular form). Comments are made in the associated text relative to the correlation between the limited and the detailed test results. The equipments on which transmission characteristic tests were performed, and the extent of testing of each unit, are as follows:

AN/TTC-12	Extensive testing SN 1 (Serial No. 1). No testing SN 2, due to unavailability of equipment. Limited testing SN 3.
AN/TTC-13	Extensive testing SN 1. No testing SN 2, due to unavailability of equipment.

AN/TTC-14	Limited testing SN 001, 011, 012. Limited testing SN 002. Extensive testing SN 003.
AN/TTC-15	Extensive testing SN 1. Limited testing SN 2. Limited testing SN 3. Limited testing SN 4.
TA-375/TTC	Limited testing SN 1. Limited testing SN 2.
TA-376/TTC	Limited testing SN 1. Limited testing SN 2.
TA-344/G	Extensive testing SN 1, 2 and 3.
AM-2261/TT	Limited testing, one unit.
SB-1191	Limited testing SN 1.
SB-22/PT	Extensive testing, one unit.
SB-86/P	Extensive testing, one unit.
AN/TTC-7	Extensive testing, one unit.
AN/TCC-3	Extensive testing, one unit.
AN/TCC-7	Extensive testing, one unit.

1.5 Section 3.0 presents the results of interoperational and compatibility testing. The capability of the new automatic, electronic equipments to operate together, and with the existing, operational equipments, is determined and described. In addition to the equipments listed in Paragraph 1.4, the interoperational and compatibility tests include the following equipments:

AN/TRC-24	Radio Set
AN/MRC-80	Radio Set (Tropospheric Scatter)
WD-1	Field Wire
WF-16	Field Wire
TT-4/TG	Teletype
AN/FGC-25	Teletype
TT-1F-TXC-1	Facsimile

2.0 BASIC TRANSMISSION TEST RESULTS

2.1 TEST OF AN/TTC-12 AUTOMATIC ELECTRONIC SWITCHING CENTRAL

2.1.1 GENERAL DESCRIPTION OF EQUIPMENT

The AN/TTC-12 is a transportable, transistorized, completely automatic, 200 line, local telephone switching central. The central utilizes a time-division multiplexing principle with pulse-amplitude modulation on a four wire basis. It is permanently housed in a S-141 shelter and can be mounted on a two and one half ton cargo truck. The equipment operates from 120 volt commercial lines or a 10 KW, 120 volt engine-driven power unit.

2.1.2 OPERATIONAL DESCRIPTION

The switching central is capable of handling sixty simultaneous calls and provides access for the following: (a) 200 local lines, (b) six trunk groups which provide trunks to six other local switching centrals. A total of fifty trunks may be terminated in these trunk groups, providing not more than twenty five trunks are connected to any one of the six groups, (c) one long distance trunk group with a maximum capacity for thirty line distance trunk terminations, which provide access to the long distance switching system, (d) one operator's position.

The following types of calls may be keyed: (a) local telephone to local telephone connected to the same local board, (b) local telephone to local telephone through two or more local boards over dial to dial trunks, (c) local telephone to local telephone through one or more long distance boards and a local board, (d) local telephone to local board operator, (e) local telephone to long distance operator, and (f) local telephone to local telephone through a tandem system.

To make a local call the calling telephone keys three digits on its keyboard. The first digit selects the local group (1 or 2) and the second and third digit selects the line within the group (01-99). The operator can be called by keying 0.

To make calls to other switchboards the calling telephone keys directly through another local or long distance boards to reach the desired telephone. The series of digits keyed selects sequentially the group to the remote board and then the group and line of the desired telephone from the remote board.

2.1.3 TECHNICAL DESCRIPTION

(1) Total lines and trunks 280
(2) Local lines served 200
(3) Dial to dial trunks served 50
(4) Long distance trunks served 30
(5) Signalling - all signalling is done by single or compound tones.
(6) Signalling Code Assignment

S - 1700 cps	X - 2500 cps
U - 1900 cps	Y - 2700 cps
V - 2100 cps	Z - 2900 cps
W - 2300 cps	

Digital Signals

1 - VW	6 - YW
2 - XW	7 - VX
3 - UY	8 - UW
4 - UV	9 - VY
5 - XY	0 - UX

Dial Tone - 600 cps.
Ring Signal - 600/20 cps (1 sec on, 2 sec off)
Busy tone (line) - 600 cps (1/2 sec on, 1/2 sec off)
Busy tone (trunk) - 600 cps (1/4 sec on, 1/4 sec off)
Ring back tone - 600 cps (1 sec on, 2 sec off)
Signal duration for detection - 50 msec

(7) Channel Transmission Characteristics

Transmission Time Division Multiplexing

One frame period (32 time slots)	80	μ sec
One time slot	2.5	μ sec
Sampling time	1.25	μ sec
Guard time	1.25	μ sec
Frame repetition frequency	12.5	KC

(8) Power Requirements

Input voltage - 120 V, 60 cps, single phase
Input current (total) - 19.2 amps

2.1.4 TEST RESULTS - AN/TTC-12

2.1.4.1 INPUT IMPEDANCE

Input impedance measurements were made on random line to line and line to trunk combinations of AN/TTC-12 SN 1 (Serial Number 1) and SN 3. A plot of the most probable mean of the input impedance versus frequency of SN 1 and the range of excursion of the means with a 95 per cent confidence level is shown in Figure B-1. As shown, the input impedance of SN 1 varied from a minimum of 569 ohms at 300 cps to a maximum of 657 ohms at 1200 cps.

The average value of input impedance obtained from testing 5 lines of SN 3 is tabulated in Table B-1. The limited test results correlate closely with the statistical results obtained on SN 1.

In testing both equipments the phase angle of the impedance did not exceed 18 degrees.

2.1.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on random line to line and line to trunk combinations of the AN/TTC-12 SN 1 and SN 3. A plot of the most probable mean of the output impedance of SN 1 versus frequency and the range of excursion of the means with a 95 per cent confidence level is shown in Figure B-2. As shown, the output impedance of SN 1 varied from a minimum of 562 ohms at 300 cps to a maximum of 659 ohms at 4000 cps.

The average value of output impedance obtained in testing 5 lines of SN 3, tabulated in Table B-1, is in agreement with the statistical results on SN 1.

The phase angle of the output impedance for the two boards did not exceed 28 degrees.

2.1.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on random line to line and line to trunk combinations of AN/TTC-12 SN 1 and SN 3, using an input signal level of -4 dbm. A plot of the most probable mean of frequency response for SN 1 is shown in Figure B-3. Since the average range of excursion of the means for a 95 per cent confidence level was only 0.23 db, the range of the means was not shown in the figure. The insertion loss at 1000 cps was found to be 0.29 db.

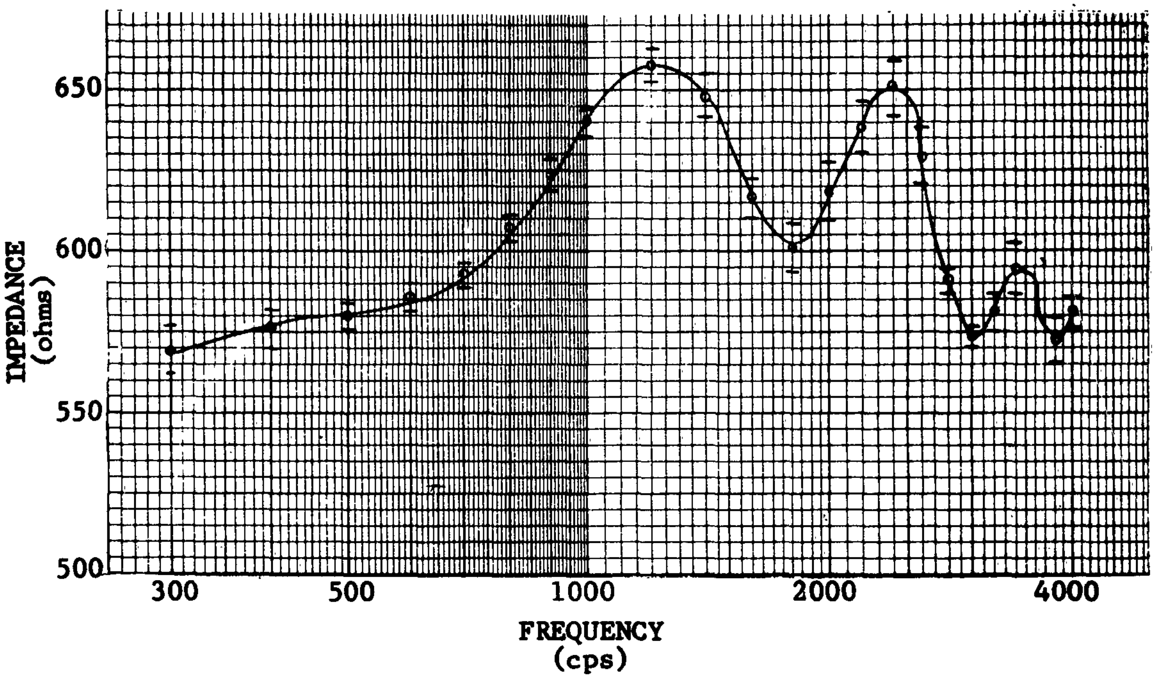


FIGURE B-1

INPUT IMPEDANCE - AN/TTC-12 SN 1
Statistically Derived

TABLE B-1

INPUT AND OUTPUT IMPEDANCE AN/TTC-12 SN 3
(Lines Tested 5)

FREQUENCY (cps)	INPUT IMPEDANCE (Ohms)	OUTPUT IMPEDANCE (Ohms)
300	573	569
400	578	589
500	577	598
600	583	608
700	592	611
800	604	615
900	621	613
1000	635	612
1200	658	612
1400	653	616
1600	626	616
1800	610	635
2000	617	634
2200	638	629
2400	650	628
2600	627	632
2800	587	646
3000	570	654
3200	580	653
3400	594	652
3600	584	641

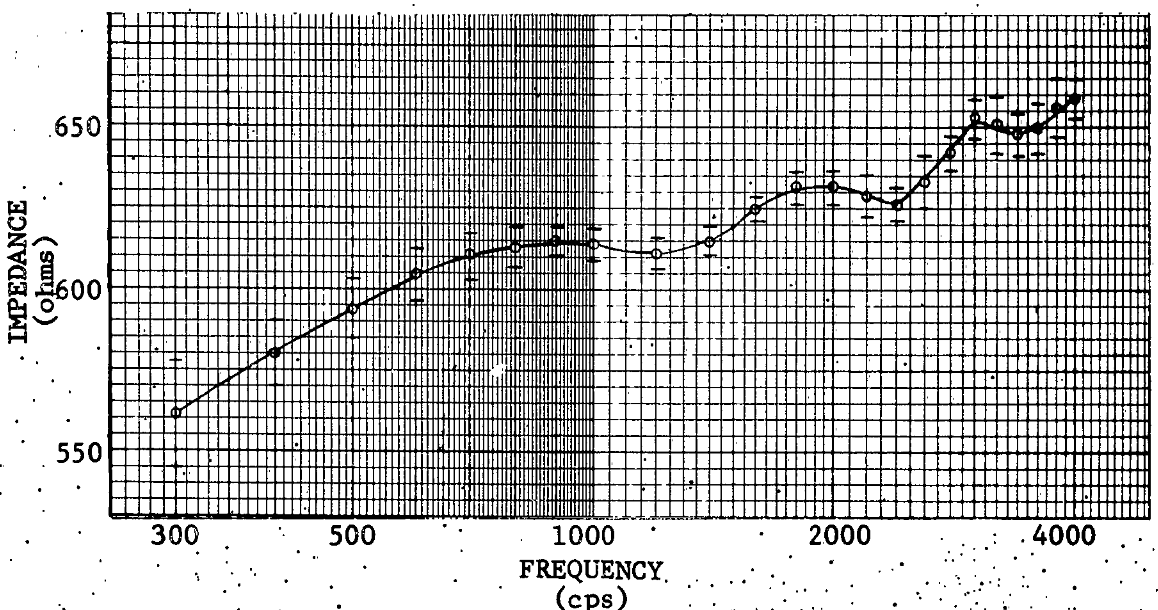


FIGURE B-2

OUTPUT IMPEDANCE - AN/TTC-12 SN 1
Statistically Derived

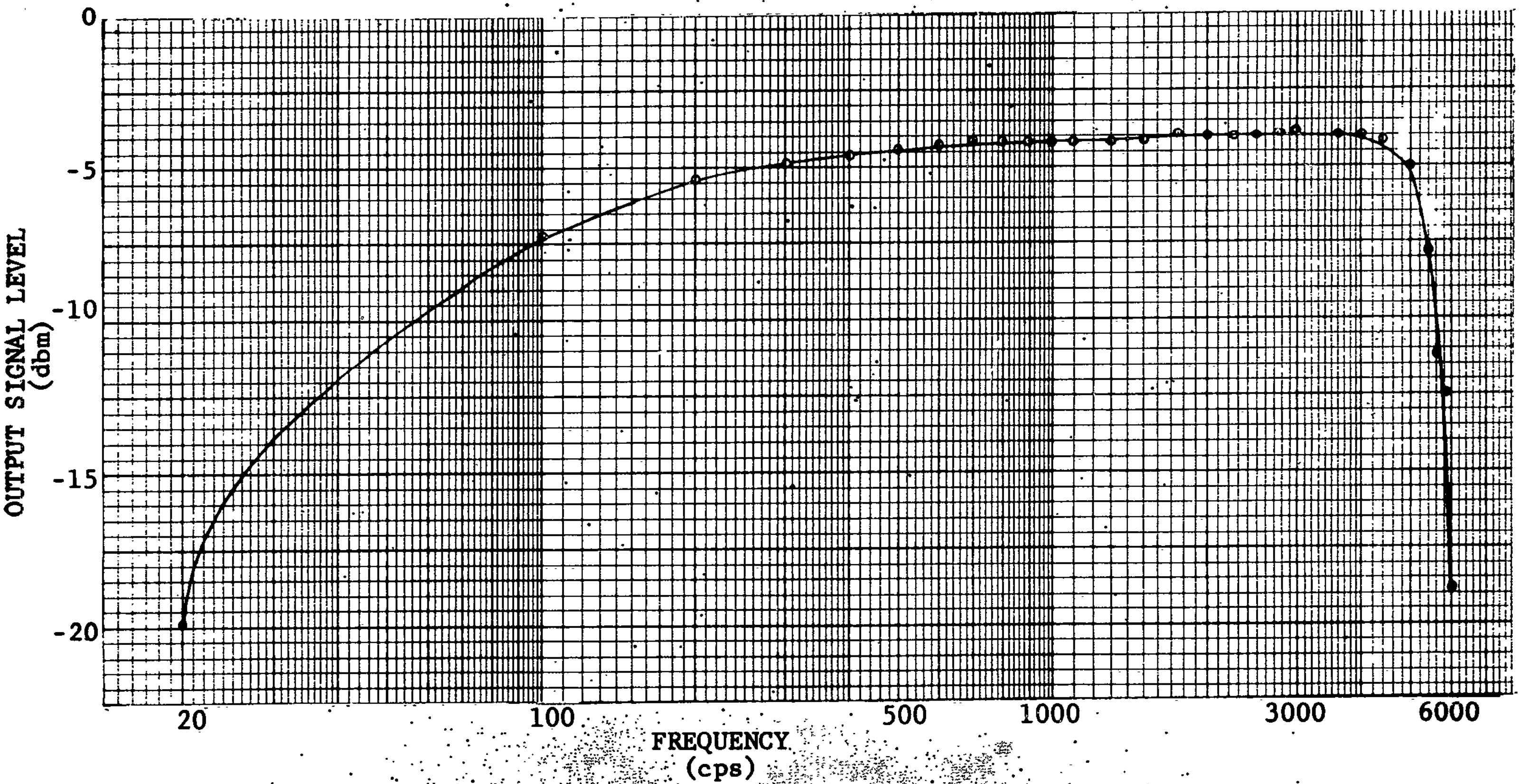


FIGURE B-3

FREQUENCY RESPONSE - AN/TTC-12 SN 1
Statistically Derived
Input Level -4 dbm

Frequency response measurements were also made on 15 line/trunk combinations of SN 3. The average value obtained for these lines, as tabulated in Table B-2, correlate closely with the testing results on SN 1.

2.1.4.4 CROSSTALK LOSS

Measurements were made of near end and far end crosstalk loss on random line/trunk combinations of AN/TTC-12 SN 1 and SN 3, using 2 internal routings through the switching centrals; namely, same time slot - adjacent highway, and adjacent time slot - same highway. Figures B-4 and B-5 show the most probable mean of the crosstalk loss for these two types of internal routings in the SN 1. As shown, the crosstalk loss is more than 59 db down from the input signal (disturbing signal) level of -4 dbm for all line/trunk combinations tested. The statistical range of excursion of the mean for a 95 per cent confidence level was well under 1 db. Therefore, the range was not plotted on Figures B-4 and B-5.

The average of the crosstalk data obtained on SN 3 is tabulated in Table B-3 and shows the crosstalk loss to be more than 55 db down from the -4 dbm input signal level for all line/trunk combinations tested.

2.1.4.5 HARMONIC DISTORTION

Harmonic distortion measurements were made on random line to line and line to trunk combinations of the AN/TTC-12 SN 1 and SN 3. A plot of the most probable mean of the harmonic distortion versus frequency for SN 1 with an input level of -2 dbm is shown in Figure B-6. The range of excursion of the means with a 95 per cent confidence level was below 0.2 per cent, the accuracy of the instrumentation, hence was not plotted on the curve.

The instrumentation used in the original testing would not permit calibration of the distortion analyzer at an input signal level of -4 dbm. Therefore, a -2 dbm input level was used in testing the AN/TTC-12 SN 1. A technique, permitting use of the -4 dbm level, was later discovered and applied to all other tests.

The average harmonic distortion figures measured on 20 random line/trunk combinations of SN 3 with an input level of -4 dbm are tabulated in Table B-4.

TABLE B-2

FREQUENCY RESPONSE - AN/TTC-12 SN 3
(Lines Tested 15)
(Input Signal Level -4 dbm)

FREQUENCY (cps)	OUTPUT LEVEL (dbm)
100	- 7.34
200	- 5.61
300	- 5.12
400	- 4.84
500	- 4.69
600	- 4.57
700	- 4.55
800	- 4.48
900	- 4.49
1000	- 4.51
1100	- 4.52
1200	- 4.51
1300	- 4.51
1400	- 4.47
1500	- 4.40
1750	- 4.30
2000	- 4.26
2250	- 4.35
2500	- 4.30
2750	- 4.13
3000	- 4.06
3200	- 4.08
3400	- 4.16
3600	- 4.16
3800	- 4.11
4000	- 4.20
4200	- 4.56
4400	- 4.93
4600	- 5.05
4800	- 5.19
5000	- 5.34
5200	- 5.57
5400	- 8.27
5600	-11.50
5800	-12.61
6000	-19.22

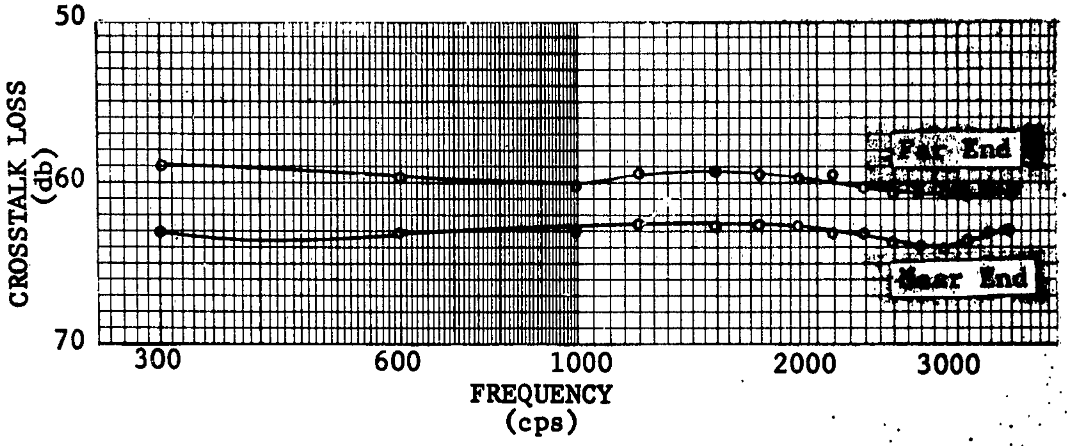


FIGURE B-4

CROSSTALK LOSS - AN/TTC-12 SN 1
SAME TIME SLOT - ADJACENT HIGHWAY
Statistically Derived
Input Level -4 dbm

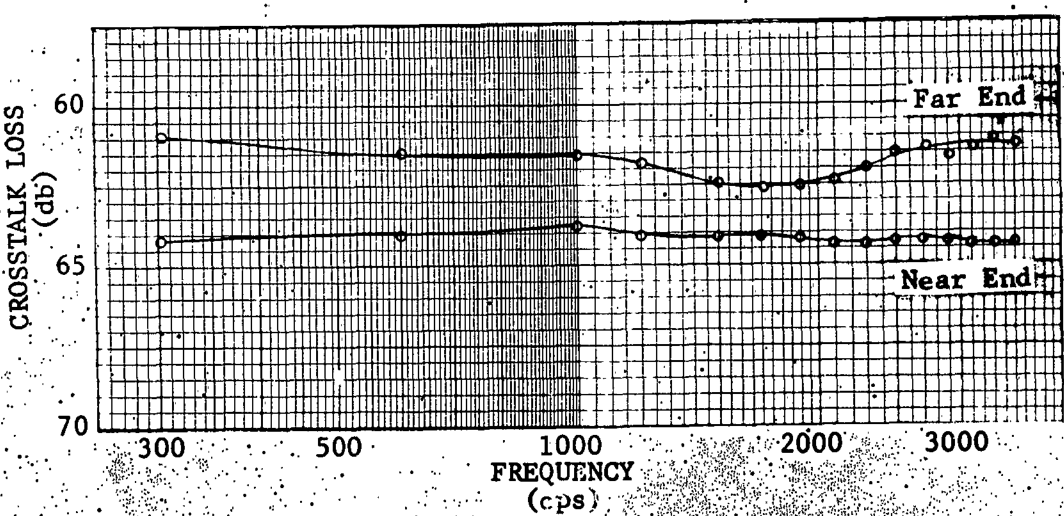


FIGURE B-5

CROSSTALK LOSS - AN/TTC-12 SN 1
SAME HIGHWAY - ADJACENT TIME SLOT
Statistically Derived
Input Level -4 dbm

TABLE B-3

CROSSTALK LOSS - AN/TTC-12 SN 3
(Lines Tested 5)
(Input Signal Level -4 dbm)

FREQUENCY (cps)	CROSSTALK LOSS (db) Same Highway Adjacent Time Slot		Same Time Slot Adjacent Highway	
	Near End	Far End	Near End	Far End
300	68	63	61	56
600	68	--	--	--
1000	68	62	62	56
1200	66	--	--	--
1500	66	62	61	56
1700	66	--	--	--
1900	65	62	61	56
2100	65	--	--	--
2300	66	62	62	56
2500	66	--	--	--
2700	66	63	63	57
2900	66	--	--	--
3100	66	63	62	57
3300	66	--	--	--
3500	67	66	62	57

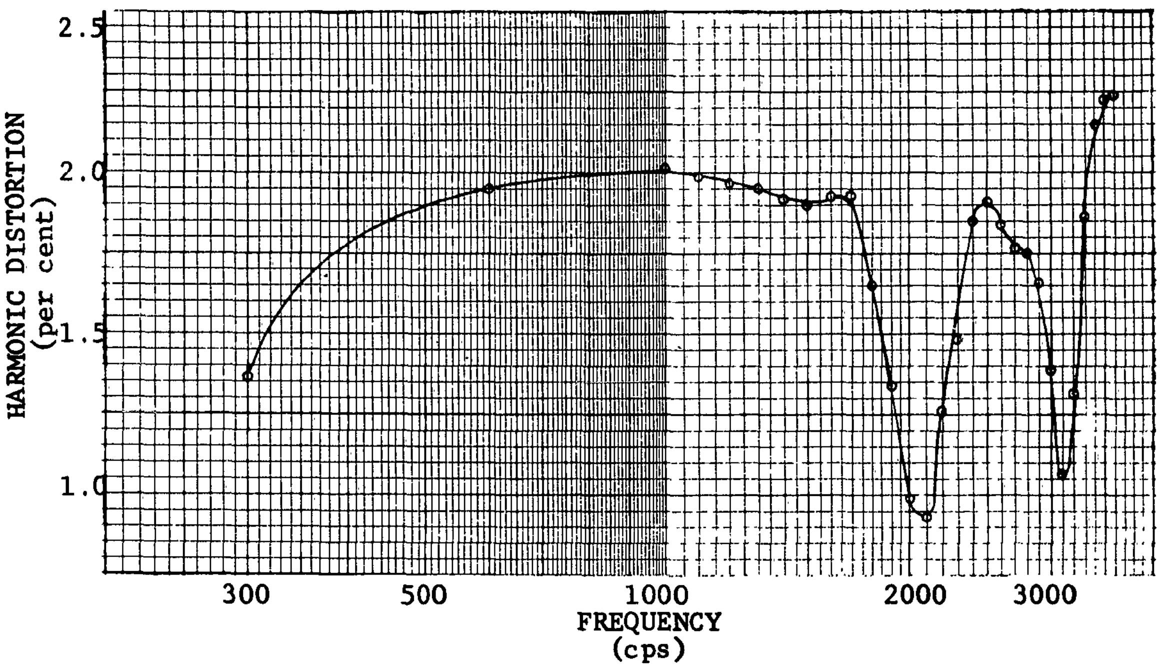


FIGURE B-6

HARMONIC DISTORTION - AN/TTC-12 SN 1
Statistically Derived
Input Level -2 dbm

TABLE B-4

HARMONIC DISTORTION - AN/TTC-12 SN 3
(Lines Tested 20)
(Input Level -4 dbm)

FREQUENCY (cps)	HARMONIC DISTORTION (Per Cent)
300	1.29
600	1.06
1000	0.97
1100	0.95
1200	0.95
1300	0.95
1400	0.93
1500	0.90
1600	0.90
1700	0.92
1800	0.81
1900	0.65
2000	0.51
2100	0.55
2200	0.70
2300	0.82
2400	1.04
2500	1.04
2600	1.02
2700	1.16
2800	1.19
2900	1.18
3000	1.13
3100	1.08
3200	1.22
3300	1.43
3400	1.61
3500	1.56
3600	1.70

The effect of limiting on harmonic distortion was determined by applying several input signal levels to a line. The line used was one which produced higher than average distortion in the earlier testing of SN 1. Figure B-7 shows curves of harmonic distortion versus frequency for input signal levels of from -2 to +4 dbm.

2.1.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on random line to line and line to trunk combinations of AN/TTC-12 SN 1 and SN 3. A pair of fundamental frequencies, f_1 and f_2, separated by 200 cps and producing a total input signal level of -4 dbm were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$), cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$), and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distortion products falling within the equipment passband were measured on SN 1 for each frequency pair and are shown in Figure B-8. All distortion products were found to be more than 35 db down from the individual fundamentals.

Intermodulation distortion products were measured on 13 line/trunk combinations of SN 3. The distortion products falling within the equipment passband were measured for each pair of fundamental frequencies and are tabulated in Table B-5. These results are in agreement with the results obtained on SN 1.

A test was performed to determine the magnitude of input signal level required to produce intermodulation distortion products less than 30 db down from the fundamental frequencies. This level was found to be +1.4 dbm.

The results of a special test on AN/TTC-12 SN1 and SN 3 using fundamental frequencies of 1250 and 1875 cps are tabulated in Table B-6. The distortion products are seen to be more than 35 db down from the fundamentals.

2.1.4.7 NOISE

Noise measurements were taken on 31 lines of SN 1 and 10 lines of SN 3, AN/TTC-12, and showed the noise level to be below 17 dba (-68 dbm) the sensitivity of the instrumentation described in the test procedures of Annex A.

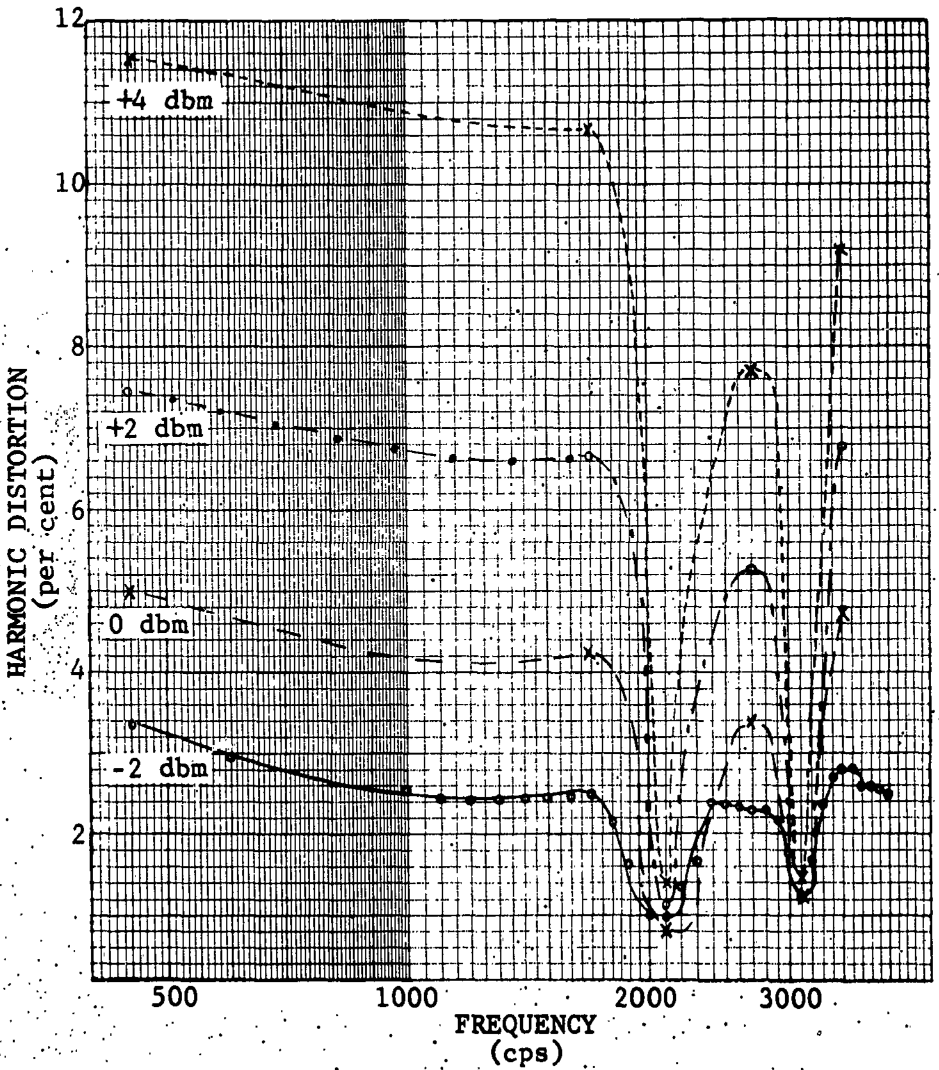
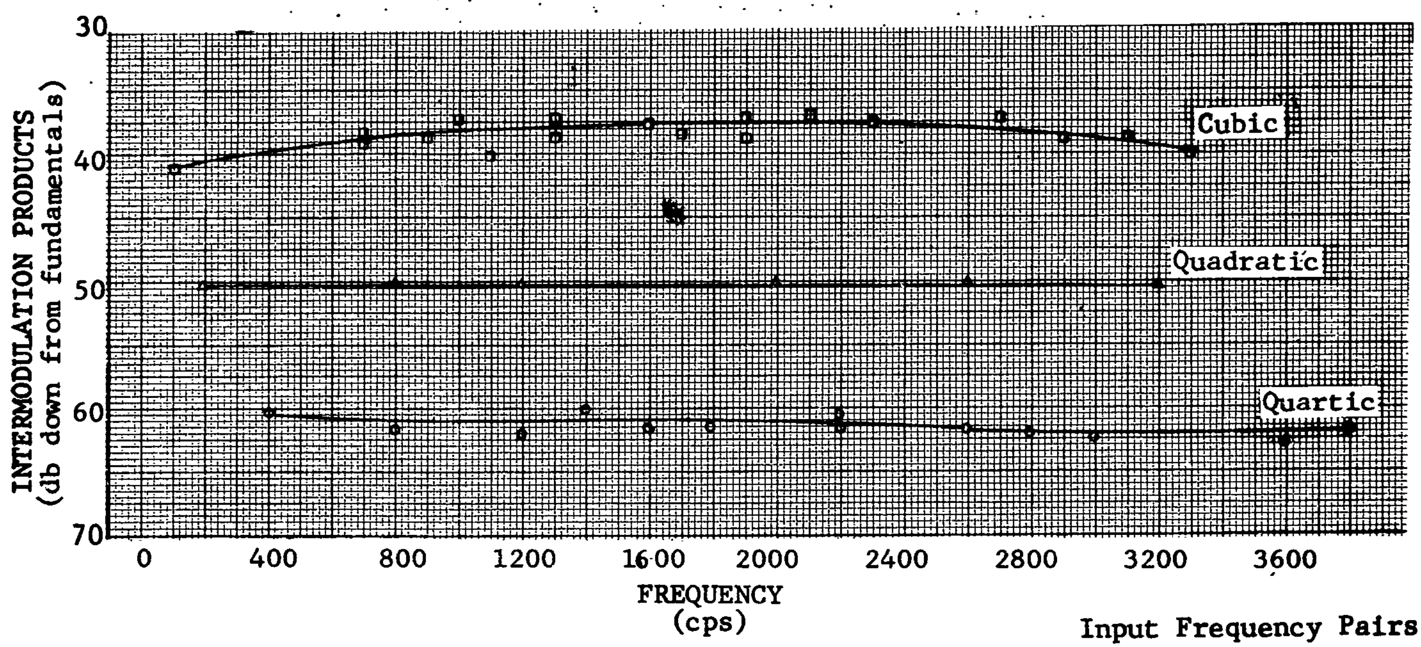


FIGURE B-7

EFFECT OF LIMITING ON
HARMONIC DISTORTION - AN/TTC-12 SN 1
Lines Tested 1



Input Frequency Pairs

300- 500
500- 700
900-1100
1200-1400
1500-1700
1900-2100
2300-2500
2500-2700
2900-3100

FIGURE B-8

INTERMODULATION DISTORTION - AN/TTC-12 SN 1
Statistically Derived
Input Level -4 dbm (total)

TABLE B-5

INTERMODULATION DISTORTION - AN/TTC-12 SN 3
(Lines Tested 13)
(Input Level -4 dbm (Total))

FREQUENCY PAIRS	INTERMODULATION PRODUCTS (db down from fundamentals)									
	F_2-F_1	F_1+F_2	$2F_1+F_2$	$2F_1-F_2$	$2F_2+F_1$	$2F_2-F_1$	$3F_1+F_2$	$3F_1-F_2$	$3F_2+F_1$	$3F_2-F_1$
300 500	47.5	48.2	40.6	43.3	41.0	39.5	61.0	60.3	60.1	61.0
500 700	47.4	47.8	40.4	41.0	40.6	39.3	60.5	62.0	60.6	60.9
900 1100	46.5	48.4	40.5	40.0	40.8	39.1	61.1	61.2	---	61.8
1200 1400	46.6	48.1	---	39.8	---	39.5	---	61.4	---	61.3
1500 1700	46.8	49.4	---	40.1	---	40.1	---	61.5	---	61.8
1900 2100	47.0	---	39.9	39.6	---	---	---	62.0	---	---
2300 2500	46.5	---	---	38.6	---	38.8	---	---	---	---
2500 2700	50.3	---	---	40.0	---	40.2	---	---	---	---
2900 3100	50.4	---	---	40.5	---	40.7	---	---	---	---

TABLE B-6

INTERMODULATION DISTORTION - AN/TTC-12 SN 1 AND SN 3
Lines Tested - 3 each
Frequency Pair - 1250 and 1875 cps

DISTORTION PRODUCT (cps)	DECIBELS DOWN FROM FUNDAMENTAL	
	SN 1	SN 3
$F_2 - F_1$(625)	38.6	43.0
$F_1 + F_2$(3125)	49.7	48.2
$2F_1 + F_2$(4375)	38.2	43.0
$2F_2 + F_1$(5000)	42.6	48.3
$2F_2 - F_1$(2500)	36.0	40.5
$3F_1 + F_2$(5625)	48.6	57.8

2.1.4.8 PHASE DISTORTION

The envelope delay time was determined on random line to line and line to trunk combinations of AN/TTC-12 SN 1 and SN 3 using input signal levels of -4 dbm. A plot of the most probable mean of the envelope delay time versus frequency on SN 1 and the range of excursion of the means with a 95 per cent confidence level is shown in Figure B-9. The high statistical variances observed at 300, 650, 700 and 1250 cps indicate phase instability at these points. Investigation of the anomalies indicates that sufficient 12.5 Kcps carrier and subharmonics are present at the input and output trunk terminals of a path through the central to interact with the input signal in such a manner as to cause this non-uniform response.

The phase distortion coefficient between 1000 and 2600 cps was found to be approximately 49 microseconds. The maximum phase distortion coefficient inferred by the ranges (excluding the data at the points of phase instability) is approximately 55 microseconds.

Figure B-10 shows a plot of the arithmetic mean of absolute phase delay of a sample containing 30 line/trunk combinations for the SN 1. This curve is presented as an aid to the interpretation of the envelope delay plot of Figure B-9.

Envelope delay measurements were made, using the Phazor 200 AB Phasemeter, on a 10 line/trunk combination of SN 3. The results of this test are tabulated in Table B-7.

The Maxson Phasemeter (accuracy 0.1 degree) became inoperative after completing the tests on SN 1. It thus became necessary to substitute the Phazor Phasemeter (accuracy 1.0 degree) for all subsequent testing. The result of this change was to reduce the accuracy of time delay measurements of individual readings from 5.5 microseconds to 55 microseconds.

2.1.4.9 LONGITUDINAL BALANCE

The longitudinal balance was measured on AN/TTC-12 SN 1 and SN 3. The balance between 31 randomly selected lines/trunks and ground on SN 1 using randomly selected links averaged more than 72.7 db below the reference signal level. Table B-8 presents a tabulation of the data obtained on SN 1.

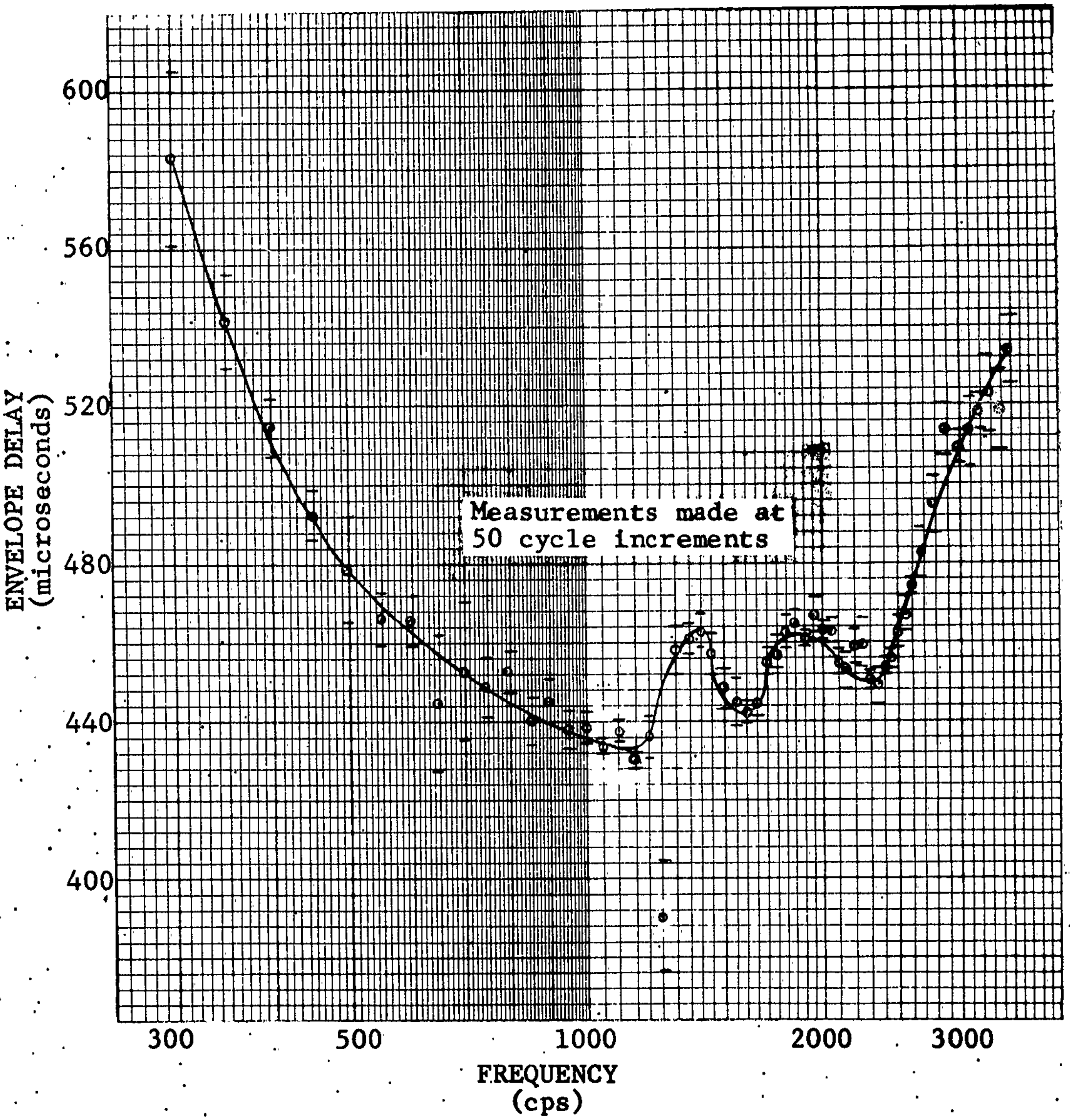


FIGURE B-9

ENVELOPE DELAY - AN/TTC-12 SN 1
Statistically Derived
Input Level -4 dbm

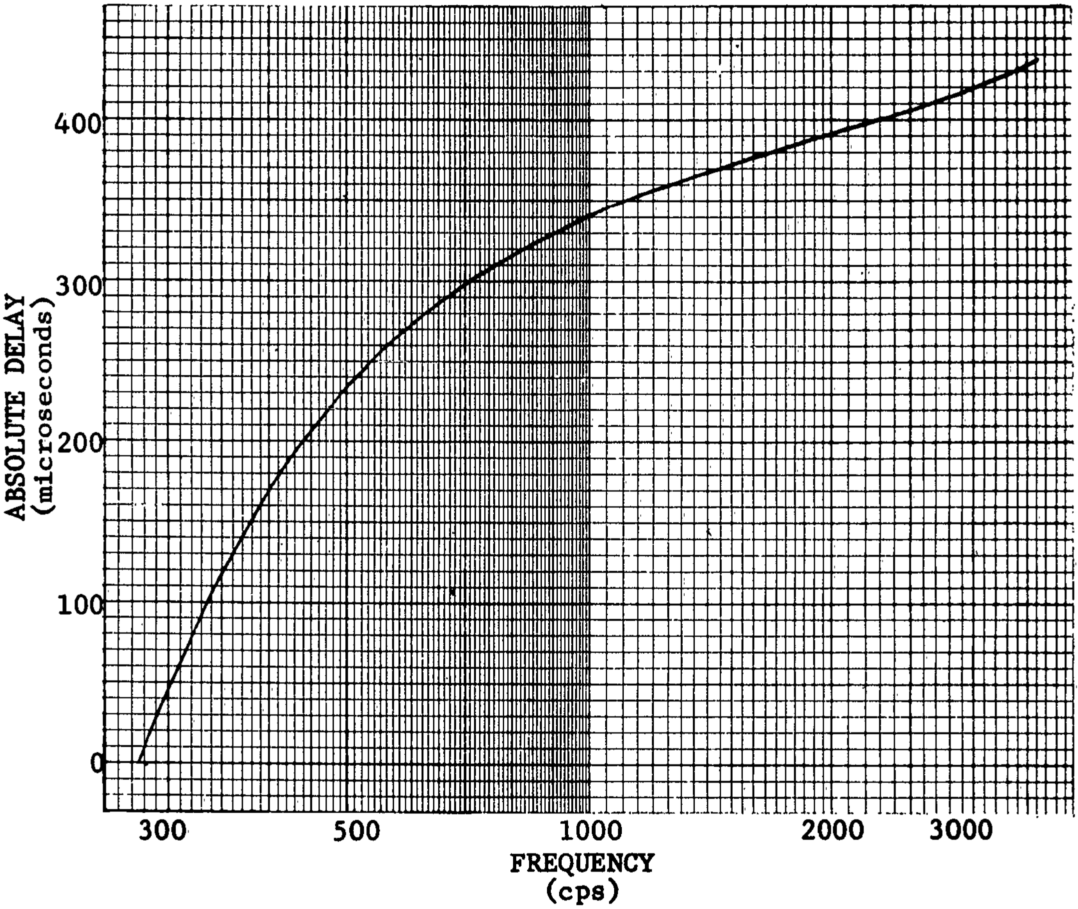


FIGURE B-10

ABSOLUTE PHASE DELAY - AN/TTC-12 SN 1
Lines Tested 30

TABLE B-7

ENVELOPE DELAY - AN/TTC-12 SN 3
Lines Tested 10
Input Level -4 dbm

FREQUENCY (cps)	ENVELOPE DELAY (Microseconds)	FREQUENCY (cps)	ENVELOPE DELAY (Microseconds)
300	580	2000	462
350	548	2050	462
400	525	2100	449
450	515	2150	446
500	538	2200	442
550	498	2250	462
600	476	2300	431
650	488	2350	438
700	450	2400	431
750	481	2450	457
800	448	2500	456
850	449	2550	467
900	435	2600	457
950	411	2650	477
1000	434	2700	481
1050	428	2750	496
1100	446	2800	515
1150	424	2850	505
1200	412	2900	485
1250	435	2950	515
1300	433	3000	520
1350	443	3050	520
1400	424	3100	508
1450	432	3150	526
1500	444	3200	518
1550	452	3250	531
1600	452	3300	520
1650	451	3350	510
1700	471	3400	531
1750	454	3450	568
1800	461	3500	515
1850	449	3550	529
1900	478	3600	567
1950	455		

TABLE B-8

LONGITUDINAL BALANCE ON AN/TTC-12 SN 1

SEND LINE	RECEIVE LINE	TRUNK	LEVEL	LINK	LONGITUDINAL BALANCE IN DECIBELS
135	264	---	---	60	70.9
297	146	---	---	7	71.7
121	240	---	---	53	75.3
235	357	---	---	13	72.2
255	218	---	---	59	74.5
154	162	---	---	26	72.5
195	186	---	---	29	70.2
219	185	---	---	41	79.8
202	212	---	---	12	68.6
267	256	---	---	14	65.5
176	119	---	---	23	72.7
227	151	---	---	43	74.5
261	143	---	---	46	71.6
180	132	---	---	25	71.5
121	167	---	---	33	75.2
156	153	---	---	54	71.0
176	224	---	---	15	71.0
162	170	---	---	21	74.5
128	119	---	---	19	75.2
270	148	---	---	7	74.9
266	---	46	3	59	75.4
281	---	4	9	33	72.4
192	---	19	9	26	69.0
180	---	15	7	50	71.3
173	---	45	6	43	69.3
149	---	14	9	19	75.1
286	---	24	4	7	72.9
196	---	22	4	34	76.4
257	---	40	7	43	75.0
132	---	18	8	4	72.2
				Average	72.8

The longitudinal balance measured on SN 3 using 15 randomly selected lines/trunks and random links averaged more than 72.4 db below the reference signal level. Table B-9 presents a tabulation of the data obtained on SN 3.

2.1.4.10 LIMITING

Limiting was measured on random line to line and line to trunk combinations of AN/TTC-12 SN 1 and SN 3. Figure B-11 is a plot of the most probable mean of limiting on SN 1, over the range of input levels from -12 to +12 dbm. Absolute limiting is observed to occur at +3.5 dbm output level. The statistical range of excursion of the means was well under 0.2 db, hence was not plotted on the figure.

The results of limiting tests on 15 line/trunk combinations of SN 3 are tabulated in Table B-10.

2.1.4.11 CARRIER LEVEL

The level of the 12.5 Kcps carrier (TDM sampling rate) was measured on random line to line and line to trunk combinations on AN/TTC-12 SN 1 and SN 3. Table B-11 presents a tabulation of carrier levels measured on 30 line/trunk combinations of SN 1. Table B-12 presents a tabulation of carrier levels measured on 16 line/trunk combinations of SN 3. All lines tested showed carrier levels to be lower than -58 dbm.

Carrier levels were not measured for the 400 Kcps master clock frequency due to the unavailability of RF wave analyzer equipment.

2.1.4.12 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits in the AN/TTC-12 SN 1 and SN 3. Figures B-12 through B-19 show the sensitivity and selectivity of the detectors in SN 1. The sensitivities of the detectors range from -35 to -45 dbm.

Figures B-20 through B-27 show plots of sensitivity and selectivity for the tone detector circuits in SN 3.

TABLE B-9

LONGITUDINAL BALANCE AN/TTC-12 SN 3

SEND LINE	RECEIVE LINE	TRUNK	LEVEL	LINK	LONGITUDINAL BALANCE IN DECIBELS
152	179	---	---	49	71.9
264	115	---	---	46	73.7
261	109	---	---	56	71.9
144	259	---	---	15	73.3
276	112	---	---	6	71.7
222	188	---	---	57	73.4
276	139	---	---	54	71.7
243	226	---	---	17	71.8
237	180	---	---	60	71.8
142	133	---	---	30	73.3
149	---	1	3	26	71.8
252	---	39	8	11	72.7
162	---	44	6	44	74.0
228	---	46	4	34	71.8
122	---	6	9	60	71.8
				Average	72.4

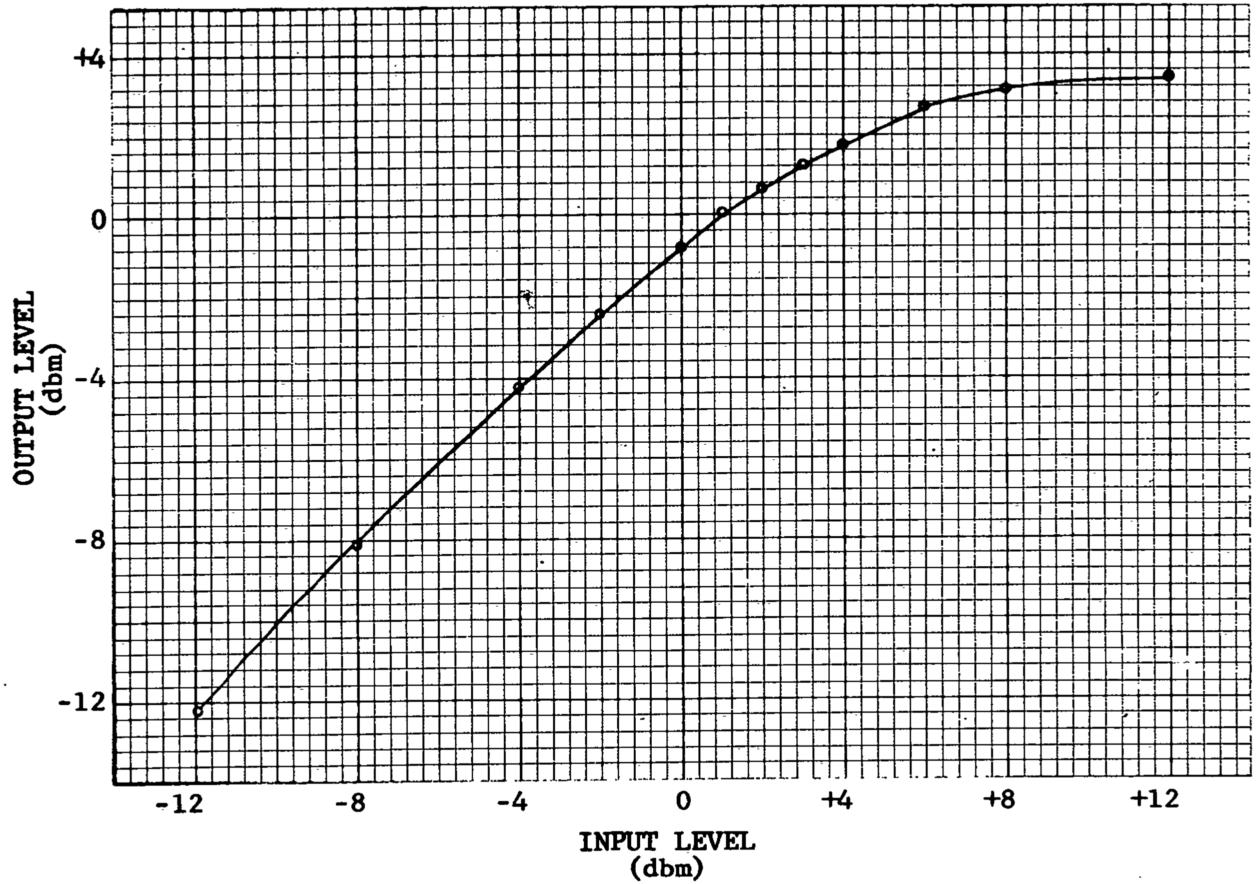


FIGURE B-11

LIMITING - AN/TTC-12 SN 1
Statistically Derived

TABLE B-10

LIMITING AN/TTC-12 SN 3
Lines Tested 15

INPUT SIGNAL (dbm)	OUTPUT SIGNAL (dbm)
-12	-11.71
- 8	- 7.86
- 4	- 3.72
- 2	- 1.85
0	- 0.33
+ 1	+ 0.02
+ 2	+ 1.01
+ 3	+ 1.79
+ 4	+ 2.46
+ 6	+ 3.47
+ 8	+ 4.04

TABLE B-11

12.5 KC CARRIER LEVEL AN/TTC-12 SN 1
Lines Tested 30

SEND LINE	RECEIVE LINE	TRUNK	LEVEL	LINK	CARRIER LEVEL (dbm)
132	112	---	---	47	-58.5
110	287	---	---	34	-62.0
271	183	---	---	13	-70.6
174	181	---	---	30	-65.0
142	120	---	---	35	-64.5
193	124	---	---	50	-61.6
114	117	---	---	38	-61.2
119	278	---	---	57	-63.2
107	131	---	---	44	-64.9
298	278	---	---	11	-62.0
206	223	---	---	60	-64.5
174	183	---	---	6	-65.0
113	207	---	---	28	-62.0
232	114	---	---	37	-61.2
181	151	---	---	7	-64.0
215	229	---	---	31	-65.2
240	137	---	---	44	-61.7
224	146	---	---	18	-63.0
282	128	---	---	17	-65.7
231	206	---	---	31	-63.9
275	---	46	5	42	-64.0
212	---	43	6	35	-62.0
127	---	43	4	54	-61.8
119	---	41	3	9	-56.2
226	---	2	3	27	-66.4
139	---	12	5	22	-61.3
209	---	28	5	12	-70.0
110	---	8	5	37	-66.3
142	---	37	7	11	-62.1
215	---	4	7	22	-60.6

Average -63.3

TABLE B-12

12.5 KC CARRIER LEVEL - AN/TTC-12 SN 3
Lines Tested 16

SEND LINE	RECEIVE LINE	TRUNK	LEVEL	LINK	CARRIER LEVEL (dbm)
164	199	---	---	26	-66.5
152	179	---	---	49	-62.2
264	115	---	---	46	-63.1
261	109	---	---	56	-59.0
144	259	---	---	15	-68.5
276	112	---	---	6	-62.5
222	188	---	---	57	-61.7
276	139	---	---	54	-62.8
243	226	---	---	17	-67.8
237	180	---	---	60	-63.3
142	133	---	---	30	-63.8
149	---	1	3	26	-65.0
252	---	39	7	11	-60.0
162	---	44	6	44	-60.5
228	---	46	4	34	-58.3
122	---	6	9	60	-62.2
				Average	-62.9

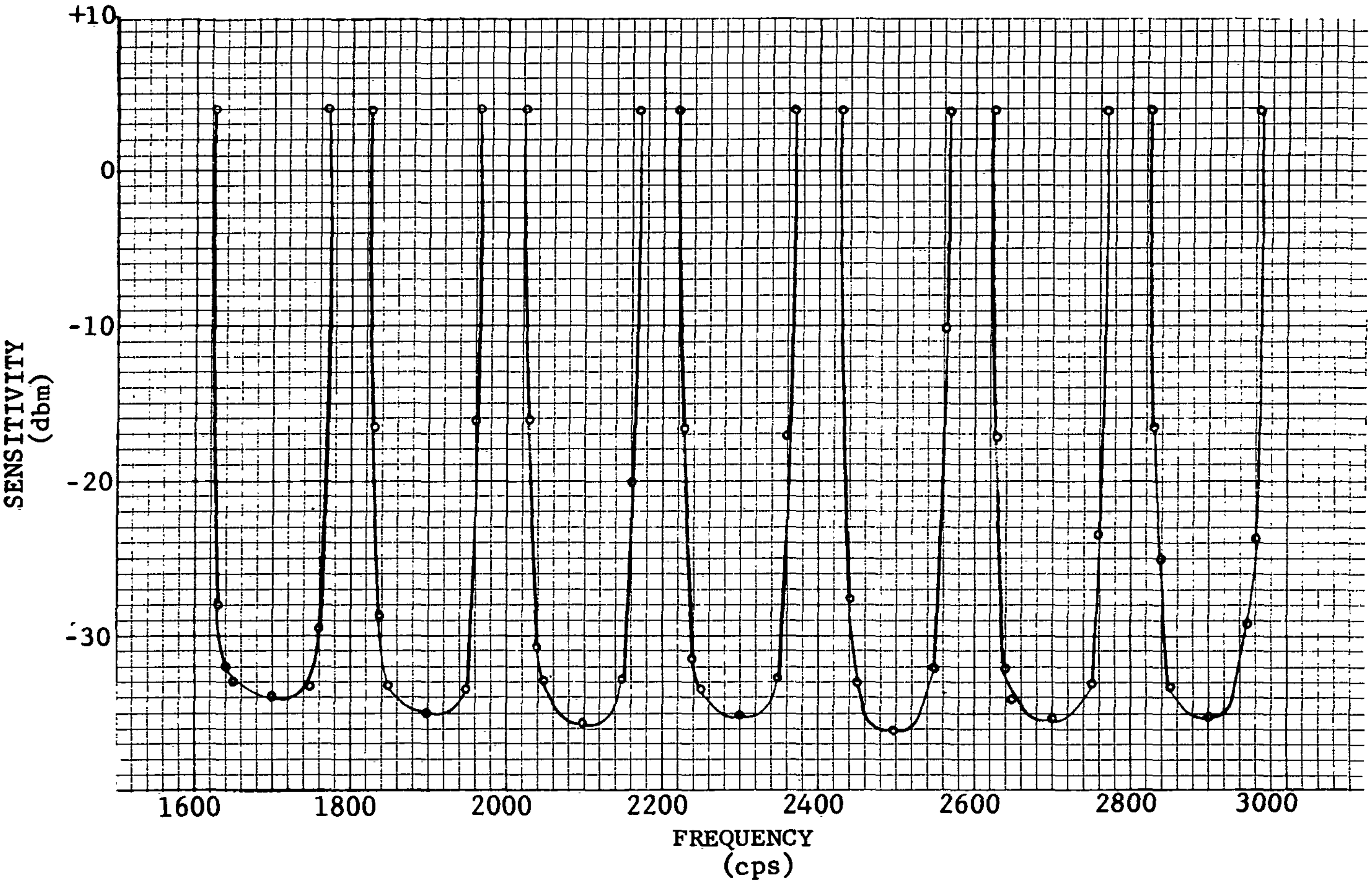


FIGURE B-12

SUBSCRIBER REGISTER SELECTIVITY CURVES
AN/TTC-12 SN 1
REGISTERS TESTED 5

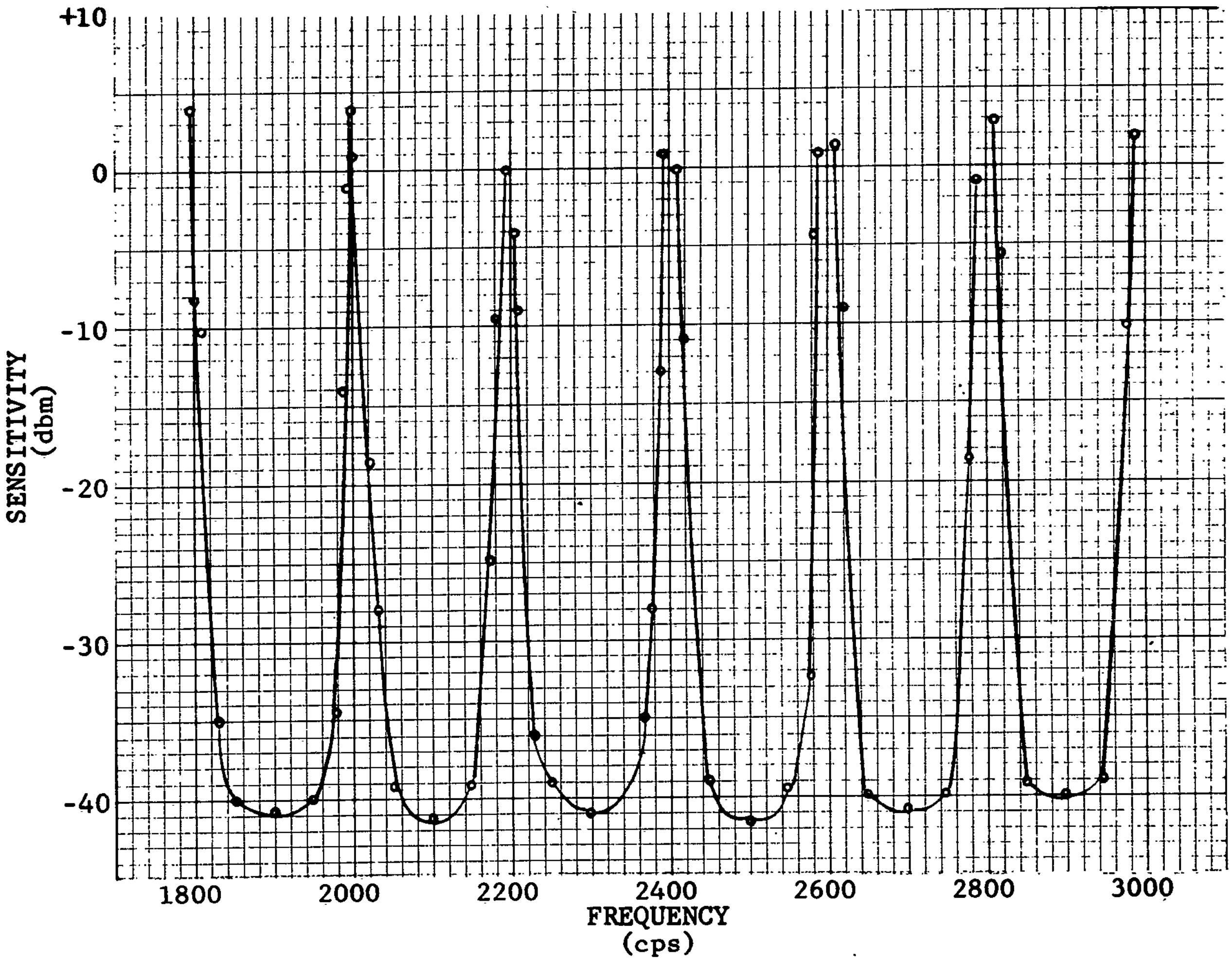


FIGURE B-13

RELEASE AND RECALL MONITOR SELECTIVITY CURVES
AN/TTC-12 SN 1
Monitors Tested All

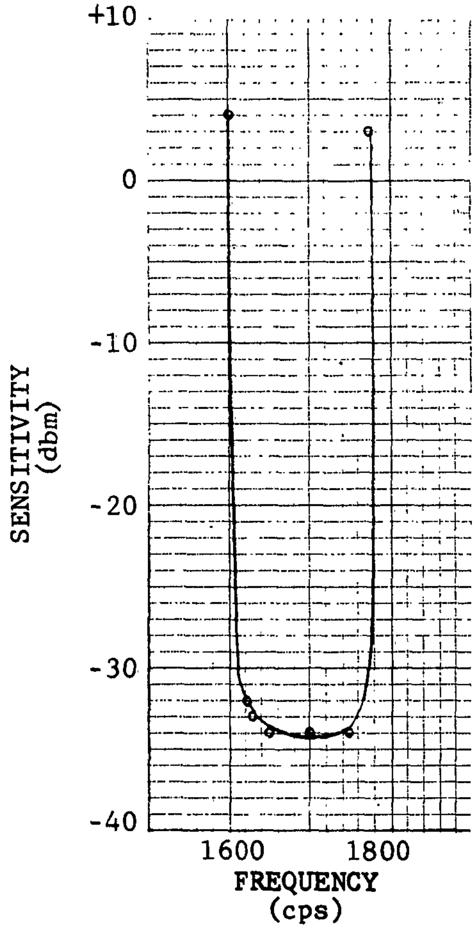
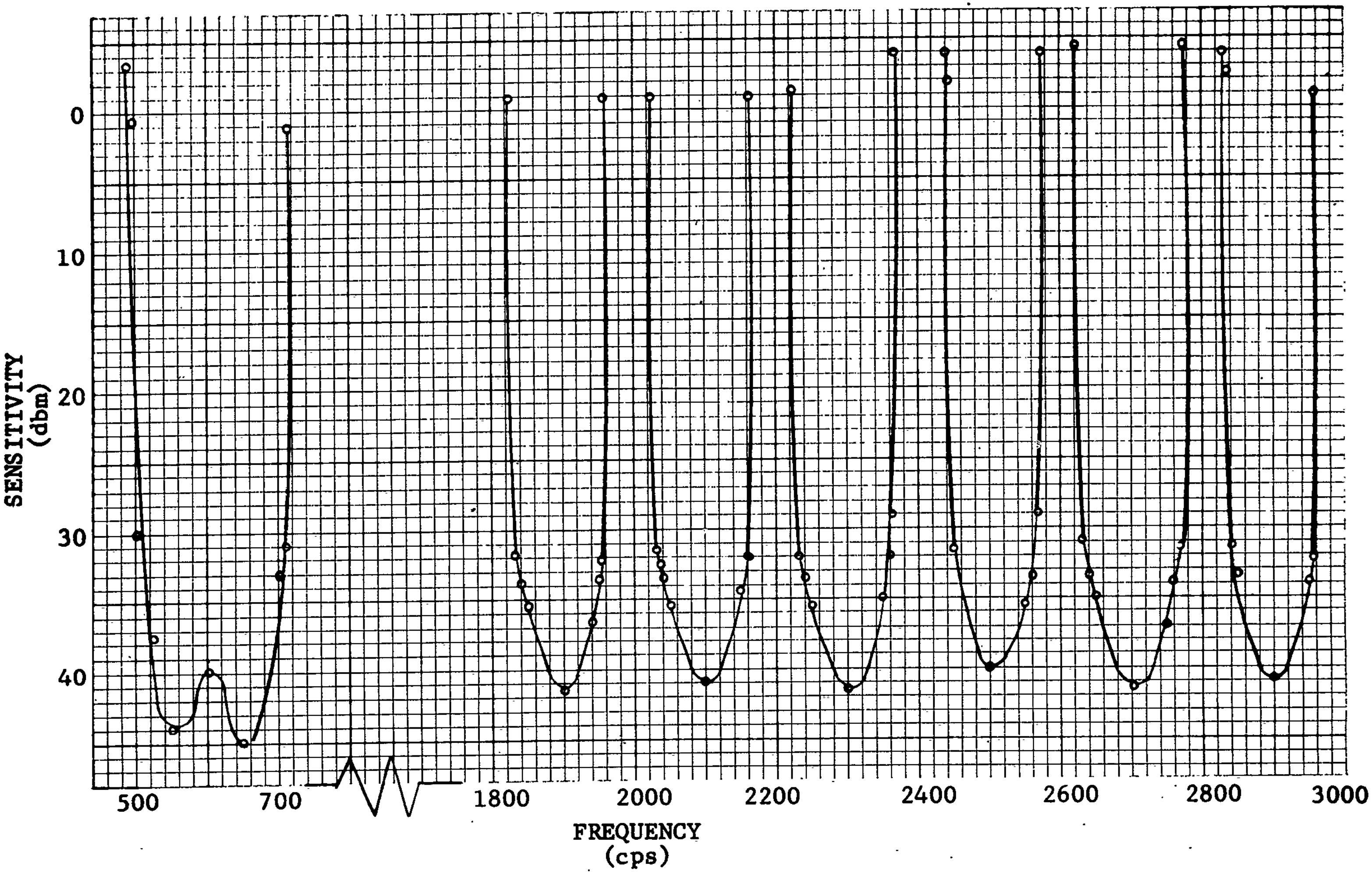


FIGURE B-14

SEIZE DETECTOR SELECTIVITY CURVE
AN/TTC-12 SN 1



POSITION REGISTER MFSD SELECTIVITY CURVES
AN/TTC-12 SN 1

FIGURE B-15

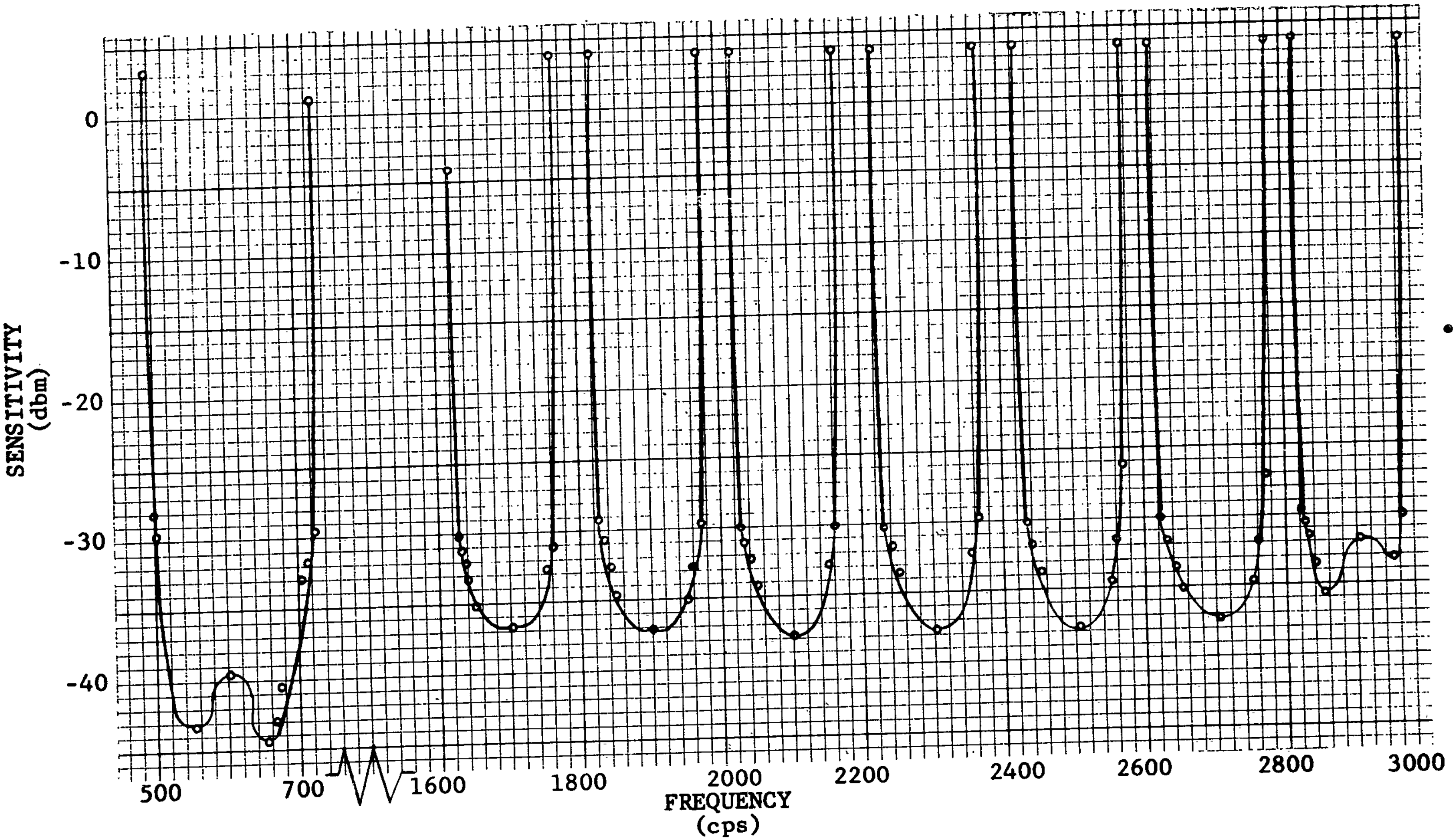


FIGURE B-16

ROUTINE TEST CIRCUIT SELECTIVITY CURVES
AN/TTC-12 SN 1

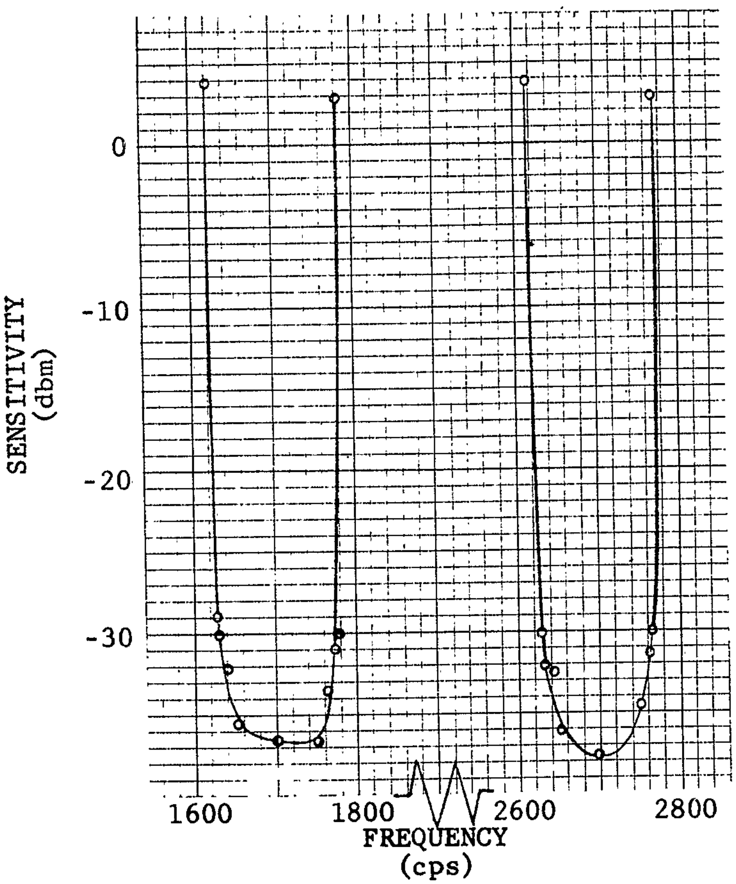


FIGURE B-17

ROUTE SELECTOR MFSD SELECTIVITY CURVES
AN/TTC-12 SN 1

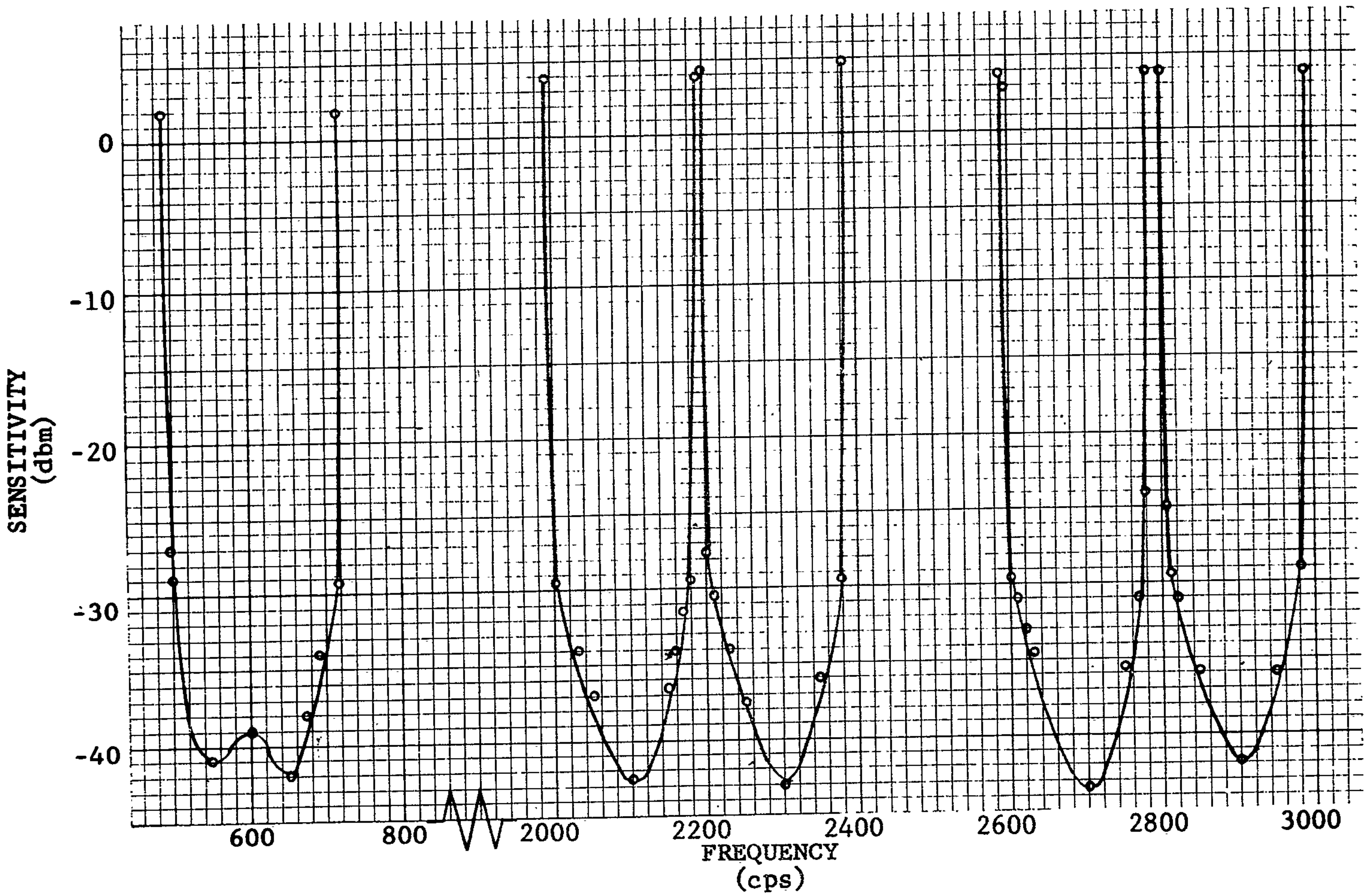


FIGURE B-18

TEST TONE ANSWERING CIRCUIT SELECTIVITY CURVES
AN/TTC-12 SN 1

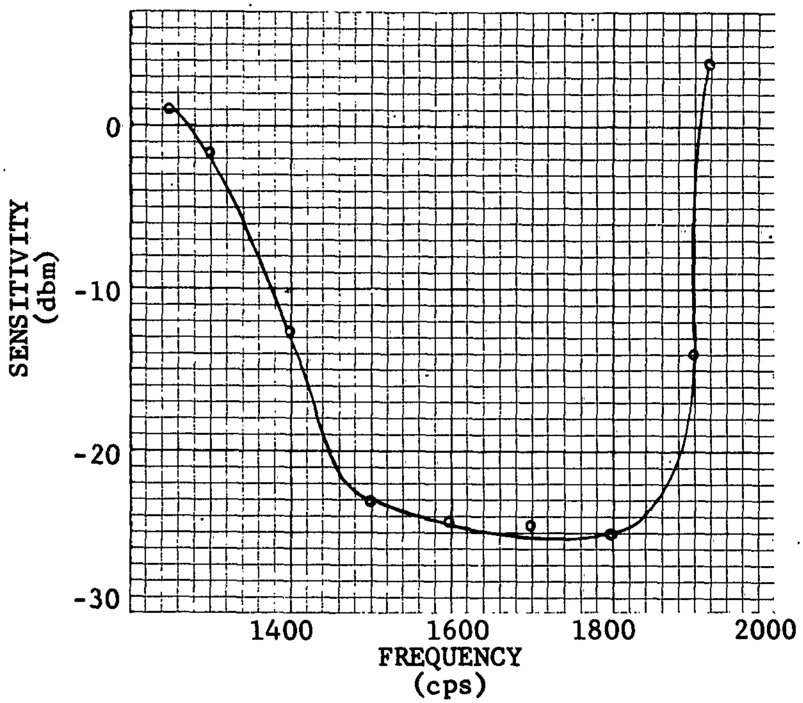


FIGURE B-19

RING TRIP DETECTOR SELECTIVITY CURVE
AN/TTC-12 SN 1

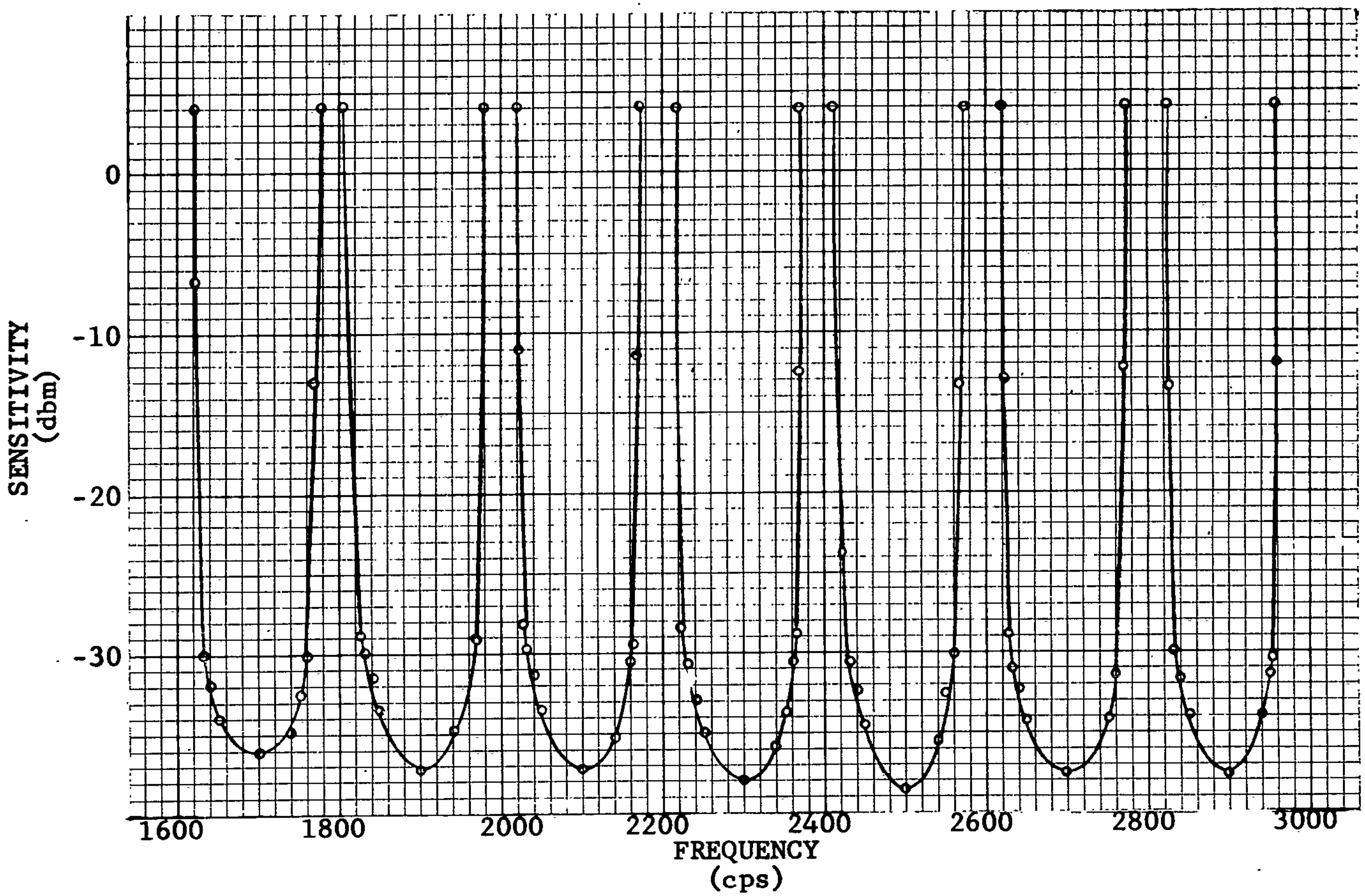


FIGURE B-20

SUBSCRIBER REGISTER SELECTIVITY CURVES
AN/TTC-12 SN 3
Registers Tested 2

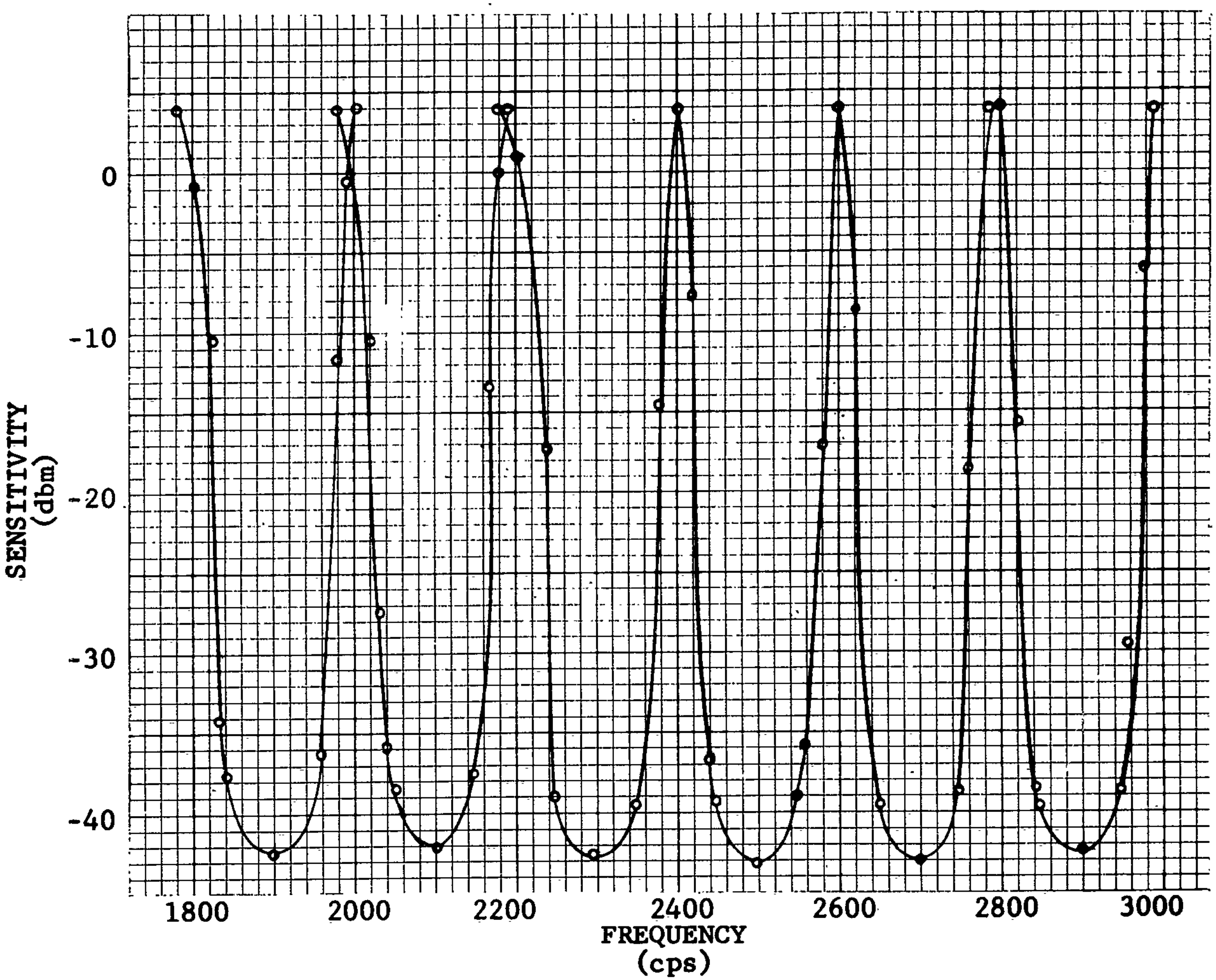


FIGURE B-21

RELEASE AND RECALL MONITOR SELECTIVITY CURVES
AN/TTC-12 SN 3
Monitor Tested Group 2 and 3

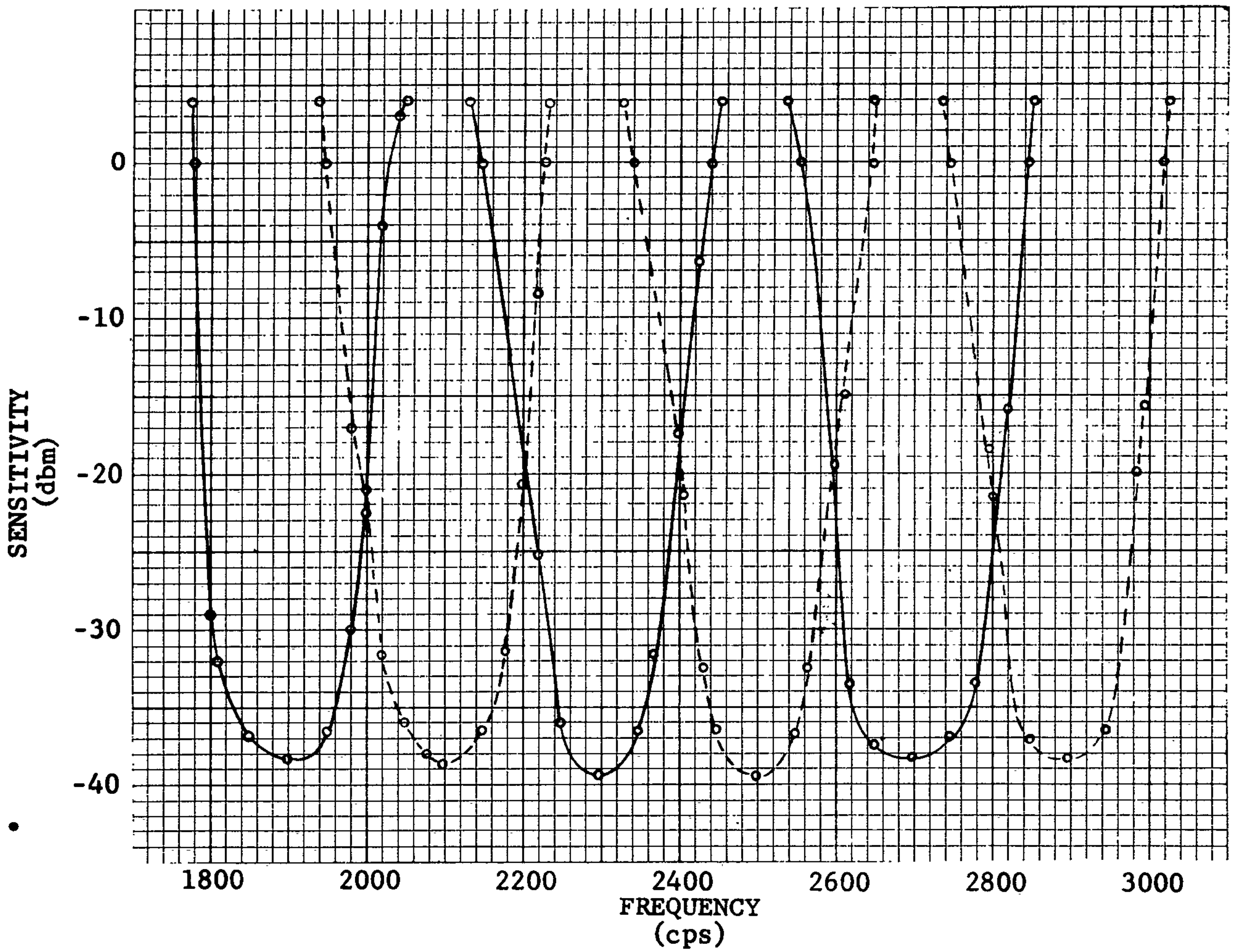


FIGURE B-22

RELEASE AND RECALL MONITOR SELECTIVITY CURVES
AN/TTC-12 SN 3
Monitor Tested - Group 1

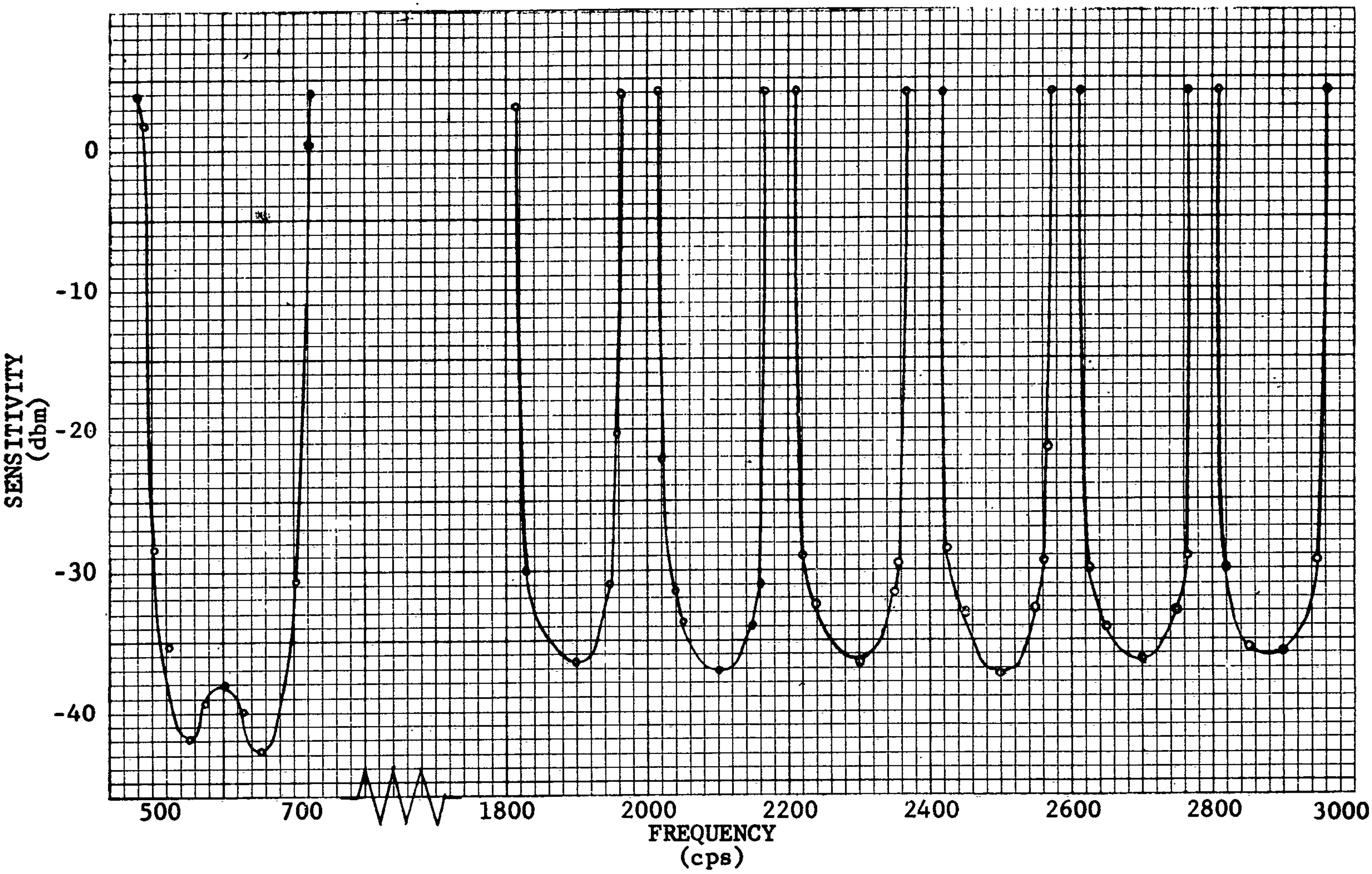


FIGURE B-23

POSITION REGISTER MFSD SELECTIVITY CURVES
AN/TTC-12 SN 3

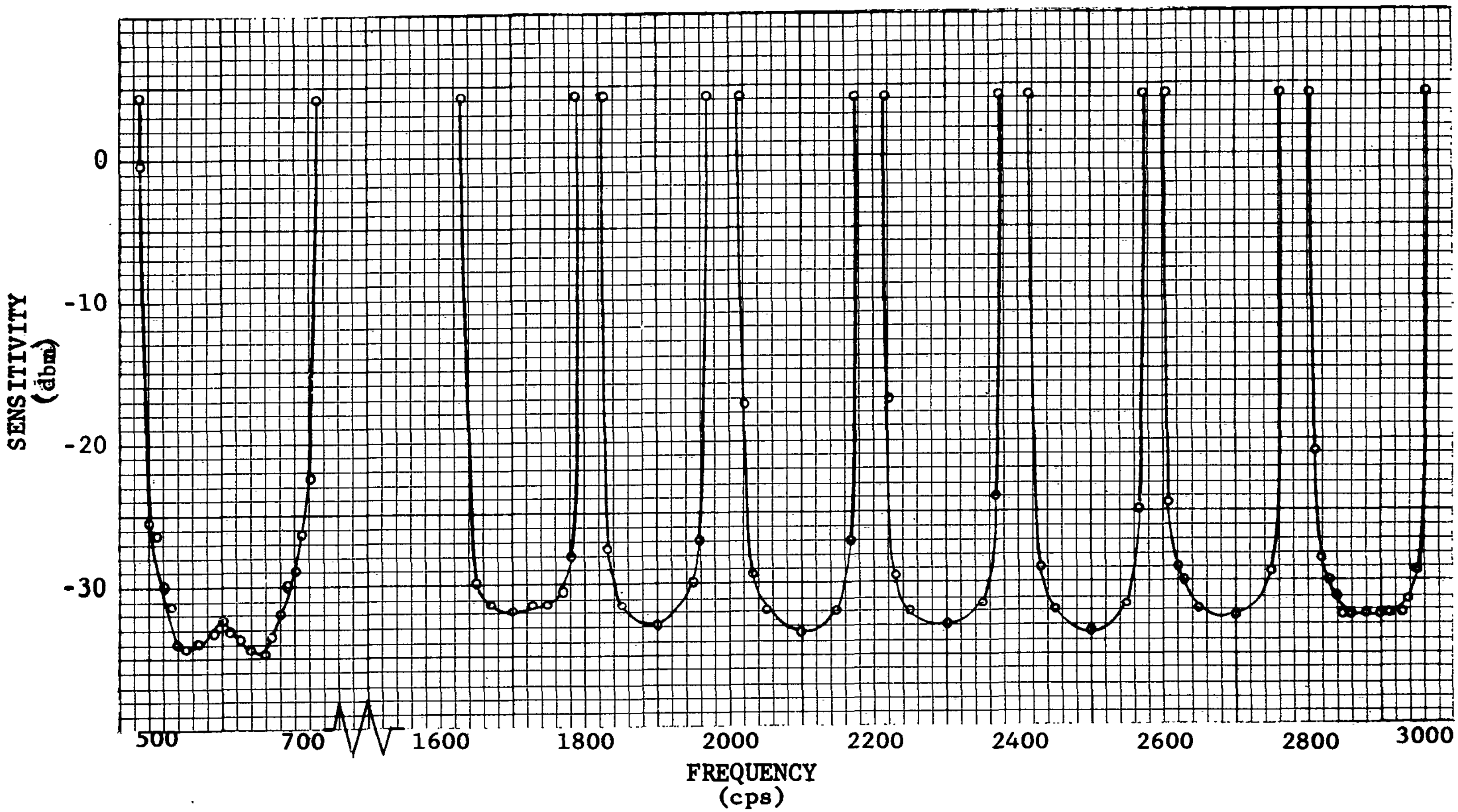


FIGURE B-24

ROUTINE TEST CIRCUIT SELECTIVITY CURVES
AN/TTC-12 SN 3

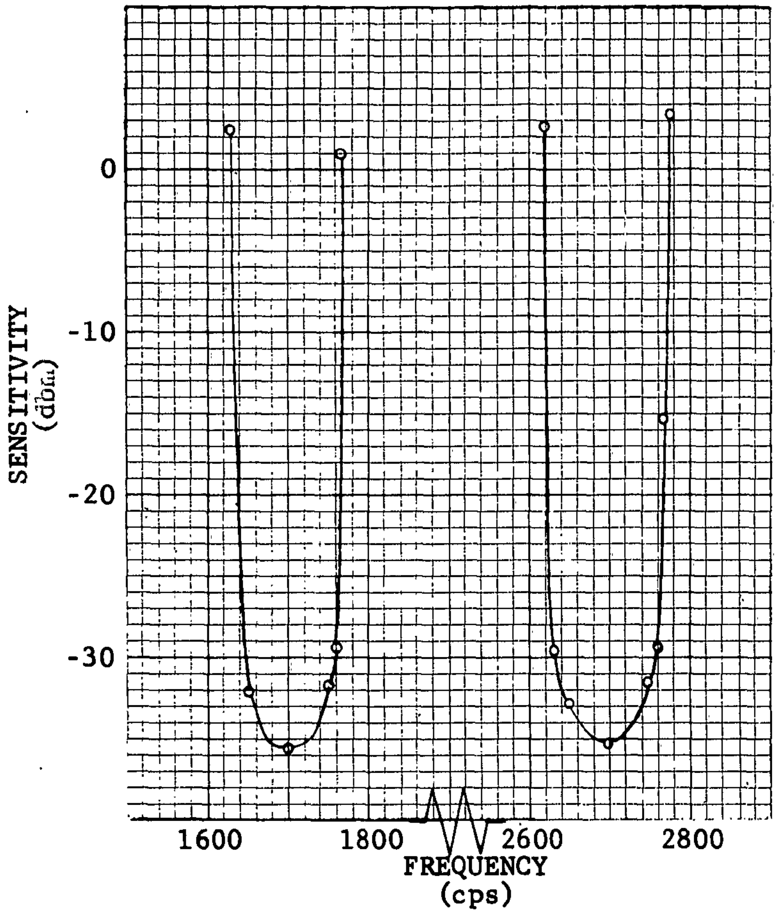


FIGURE B-25

ROUTE SELECTOR MFSD SELECTIVITY CURVES
AN/TTC-12 SN 3

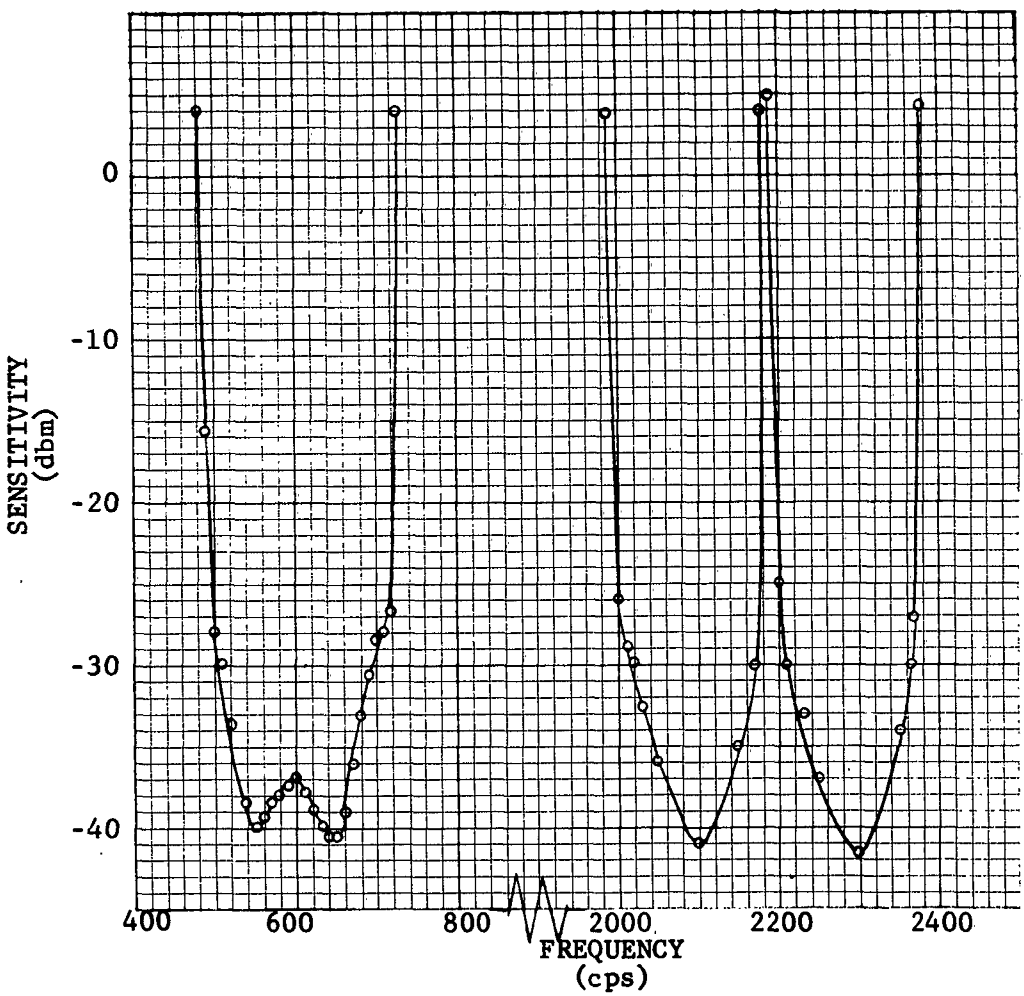


FIGURE B-26

TEST TONE ANSWERING CIRCUIT SELECTIVITY CURVES
AN/TTC-12 SN 3

NOTE: 2700 and 2900 cps filters returned for repairs.

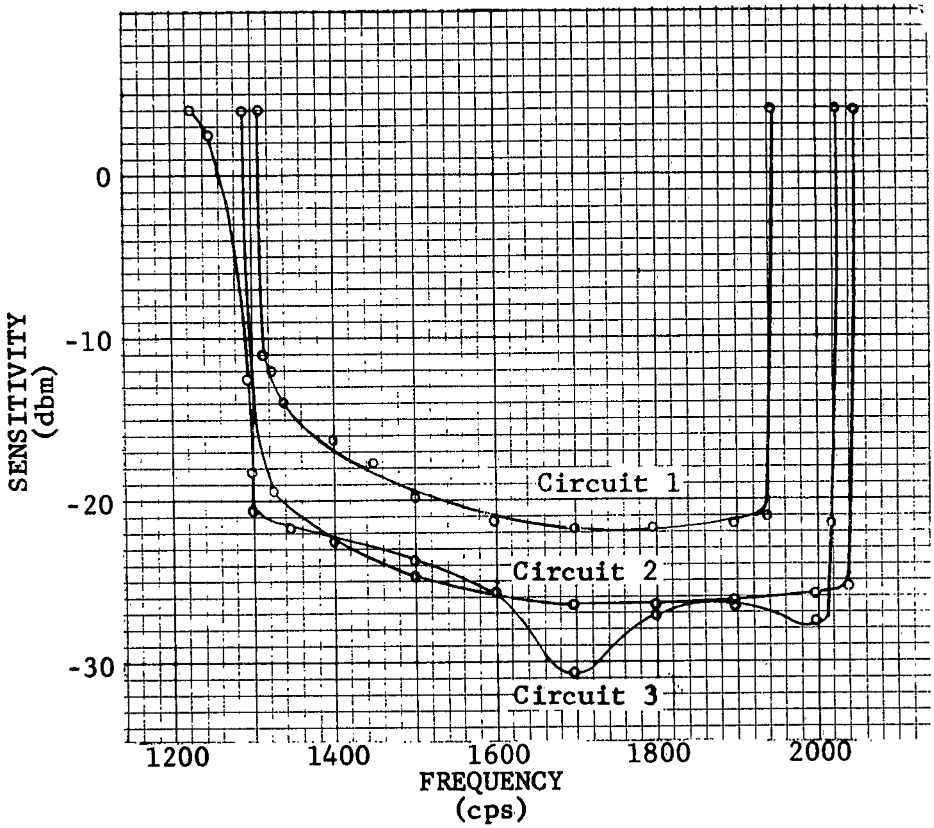


FIGURE B-27

RING TRIP DETECTOR
AN/TTC-12 SN 3

The overlapping selectivity curves of the release and recall monitor, Group 1 detector shown in Figure B-22, were found to be caused by detector circuits that were badly in need of maintenance. Groups 2 and 3, shown in Figure B-23, are representative of properly adjusted circuits.

2.1.4.13 SIGNAL SIMULATION IN SUBSCRIBER REGISTER MFSD

It was desired to determine whether random sounds or noise would have any effect on, or could actuate, the tone detectors and digit registers. Background noises, such as battle sounds, radio conversations, jamming sounds and recorded and live readings of random word lists, were applied to the equipment. The output of the tone detectors and the digit (AND/OR) detectors and the simulating signals were monitored and recorded.

Occasional simulations were recorded for background sounds, such as shrieking shells, bagpipe jamming and word lists spoken by a feminine voice. A recording of the voice of a Chinese propaganda broadcast repeating the phrase "Yankee, go home; is lost cause!" activated most of the tone and digit detectors. Further experiment determined that certain male voices repeating words containing the "nk" sounds (ink, yankee) could cause simulations of some digits and the release tone.

It was also determined that erroneous releases can be experienced when two telephone sets are operating in close physical proximity. The release tone signal, generated by hanging up one telephone, can be audibly picked up by the transmitter of the adjacent telephone and can cause undesired release of this circuit.

2.1.4.14 TONE GENERATOR OUTPUT

The frequency and power output of the several tone generators of AN/TTC-12 SN 1 and SN 3 were measured. The data obtained, measured at the output terminal of the central, are tabulated in Tables B-13 and B-14.

2.1.4.15 SIGNAL TO NOISE AND SIGNAL TO SIGNAL

Signal to noise and signal plus noise versus total signal ratios were measured on the AN/TTC-12 SN 1 and SN 3.

TABLE B-13

TONE GENERATOR OUTPUT - AN/TTC-12 SN 1

TONE GENERATORS	FREQUENCY (cps)	SIGNAL LEVEL (dbm)
Test Tone Answering Circuit	601	-21.5
Test Tone Answering Circuit	1025	- 6.5
Ringback	602	-22.5
Ring	601	+ 7.5
Line Busy	601	-18.5
Trunk Busy	601	-18.5
Dial Tone	---	---
S Tone	1702	-16.4
U Tone	1904	-17.4
V Tone	2103	-17.1
W Tone	2306	-18.6
X Tone	2504	-18.3
Y Tone	2702	-17.4
Z Tone	2903	-16.4

TABLE B-14

TONE GENERATOR OUTPUT - AN/TTC-12 SN 3

TONE GENERATORS	FREQUENCY (cps)	SIGNAL LEVEL (dbm)
Test Tone Answering Circuit	601	-21.5
Test Tone Answering Circuit	1025	- 6.5
Ringback	608	-23.4
Ring	608	+ 7.3
Line Busy	601	-15.0
Trunk Busy	601	-14.5
Dial Tone	609	-19.9
S Tone	1700	-15.0
U Tone	1903	-18.9
V Tone	2103	-18.1
W Tone	2303	-17.4
X Tone	2505	-18.5
Y Tone	2705	-18.2
Z Tone	2905	-16.0

For accuracy at the low signal levels used in this test, S/N and $\frac{S+N}{N}$ ratios were determined using millivolt measurements. Also, due to the variation of input impedance of the board, occurring at different stages of the keying sequence, db measurements would have been less accurate. Plots showing the effect of noise upon the sensitivity of detector circuitry of AN/TTC-12 SN 1 and SN 3 are shown in Figures B-28 through B-34.

Signal to signal ratios versus total signal measured on AN/TTC-12 SN 1 and SN 3 are shown in Figures B-35 through B-37.

2.2 TEST OF AN/TTC-13 AUTOMATIC ELECTRONIC SWITCHING CENTRAL

2.2.1 GENERAL DESCRIPTION OF EQUIPMENT

The AN/TTC-13 is a transportable, transistorized, completely automatic, long distance trunk switching central station. The central utilizes a time-division multiplexing principle with pulse-amplitude modulation on a four wire basis. It is permanently housed in a S-141 shelter and can be mounted on a two and one half ton cargo truck.. The equipment operates from 120 volt commercial lines or a 10 KW 120 volt engine driven power unit.

2.2.2 OPERATIONAL DESCRIPTION

The switching central is capable of handling eighty simultaneous calls and provides access for the following: (a) eight trunk groups with a total capacity for one hundred long distance trunk terminations. These groups provide automatic trunk switching to other long distance centrals, and any combination of trunks in the amount not to exceed fifty out of one hundred may be terminated on any one of the eight groups; (b) ten trunk groups which provide automatic trunk switching to ten local and/or division tandem switching centrals with a total capacity for sixty trunk terminations. Any combination of these trunks, to the total of sixty, may be terminated in any one of the ten groups; (c) two operator's positions. The operator may extend incoming calls or provide directory service; (d) no local subscriber stations are served by the AN/TTC-13.

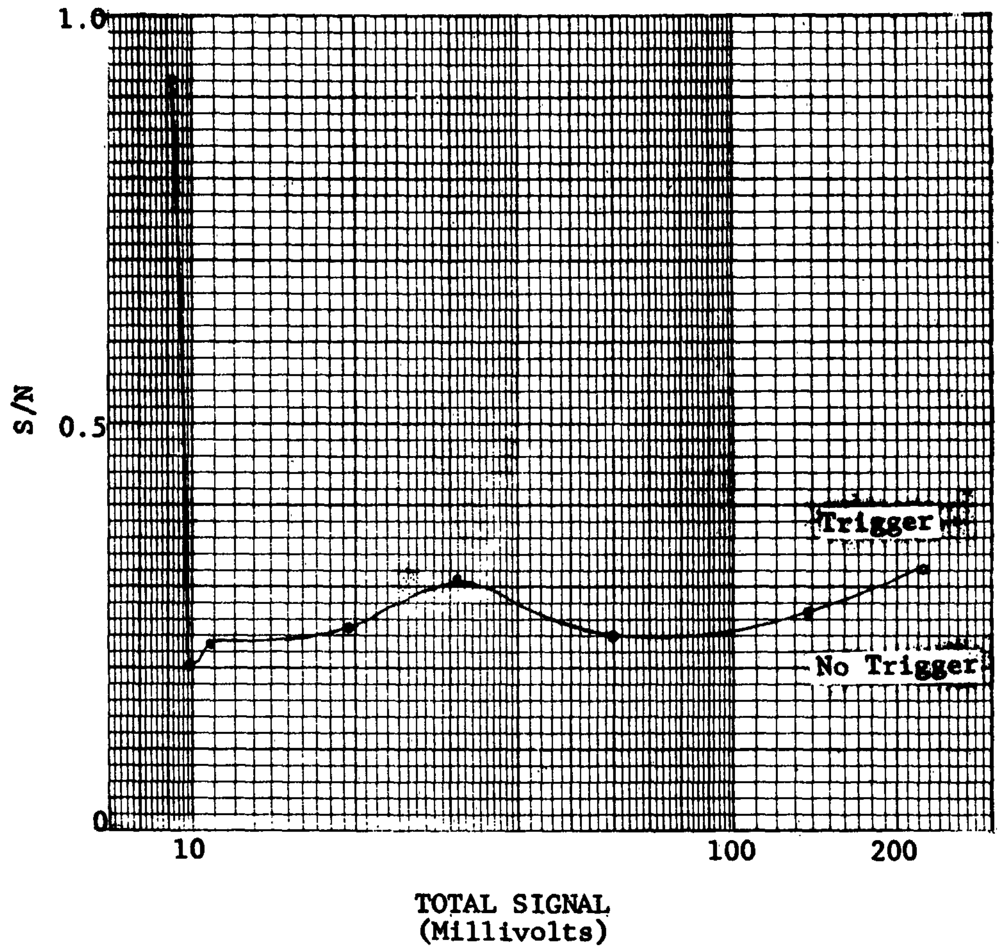


FIGURE B-28

LINK RELEASE SIGNAL TO NOISE (S/N) VERSUS TOTAL SIGNAL
AN/TTC-12 SN 1
Link No. 26

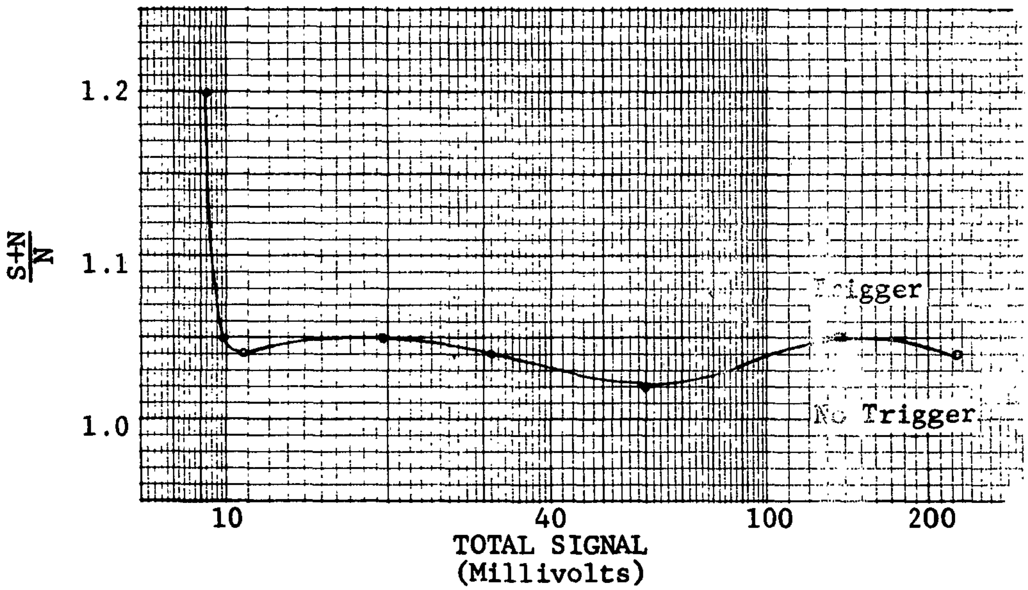


FIGURE B-29

LINK RELEASE SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-12 SN 1
LINK NO. 26

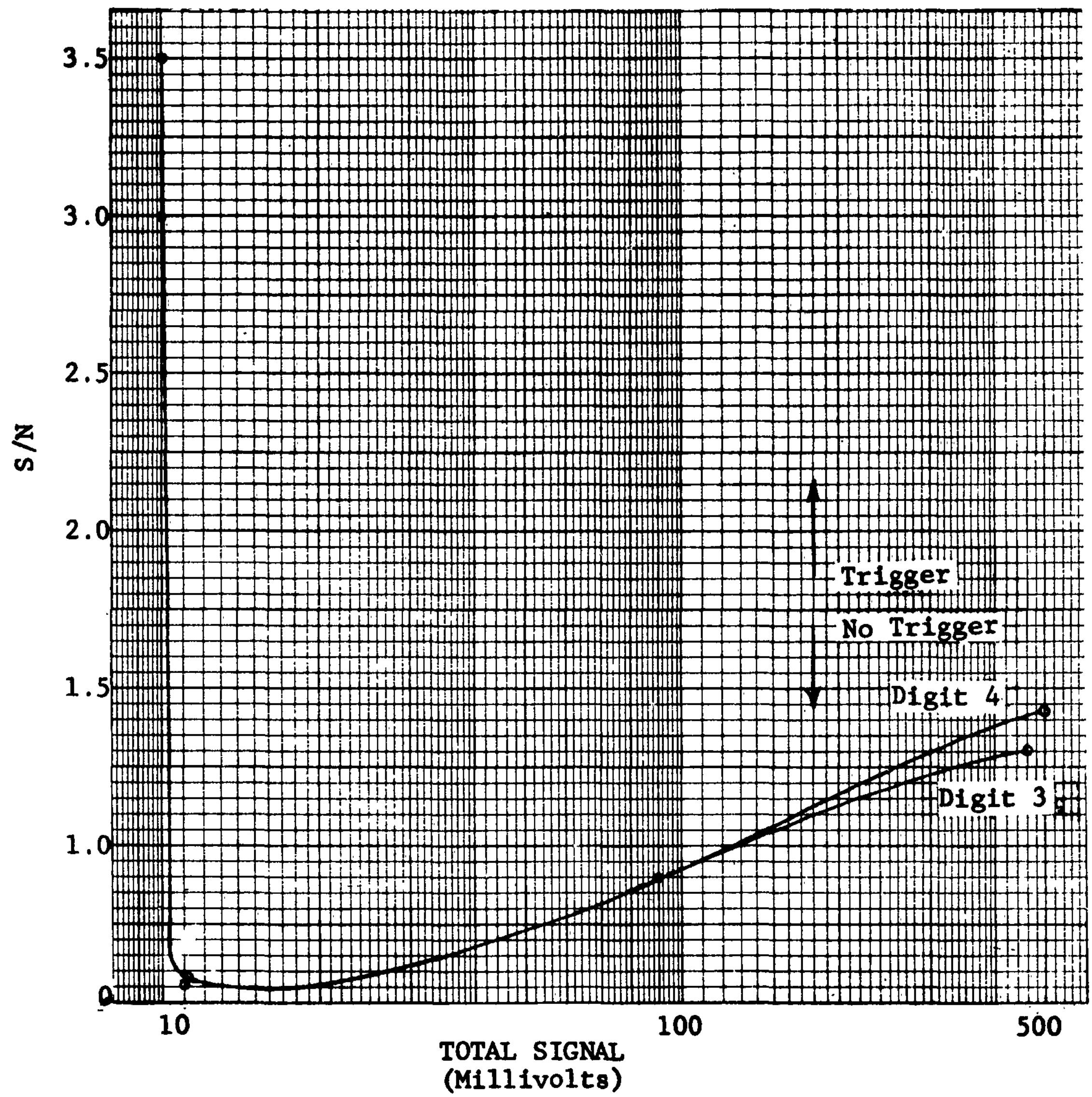


FIGURE B-30

DIGIT 3 AND 4 SIGNAL TO NOISE (S/N) VERSUS TOTAL SIGNAL
AN/TTC-12 SN 1
Unmodified Reg. No. 5

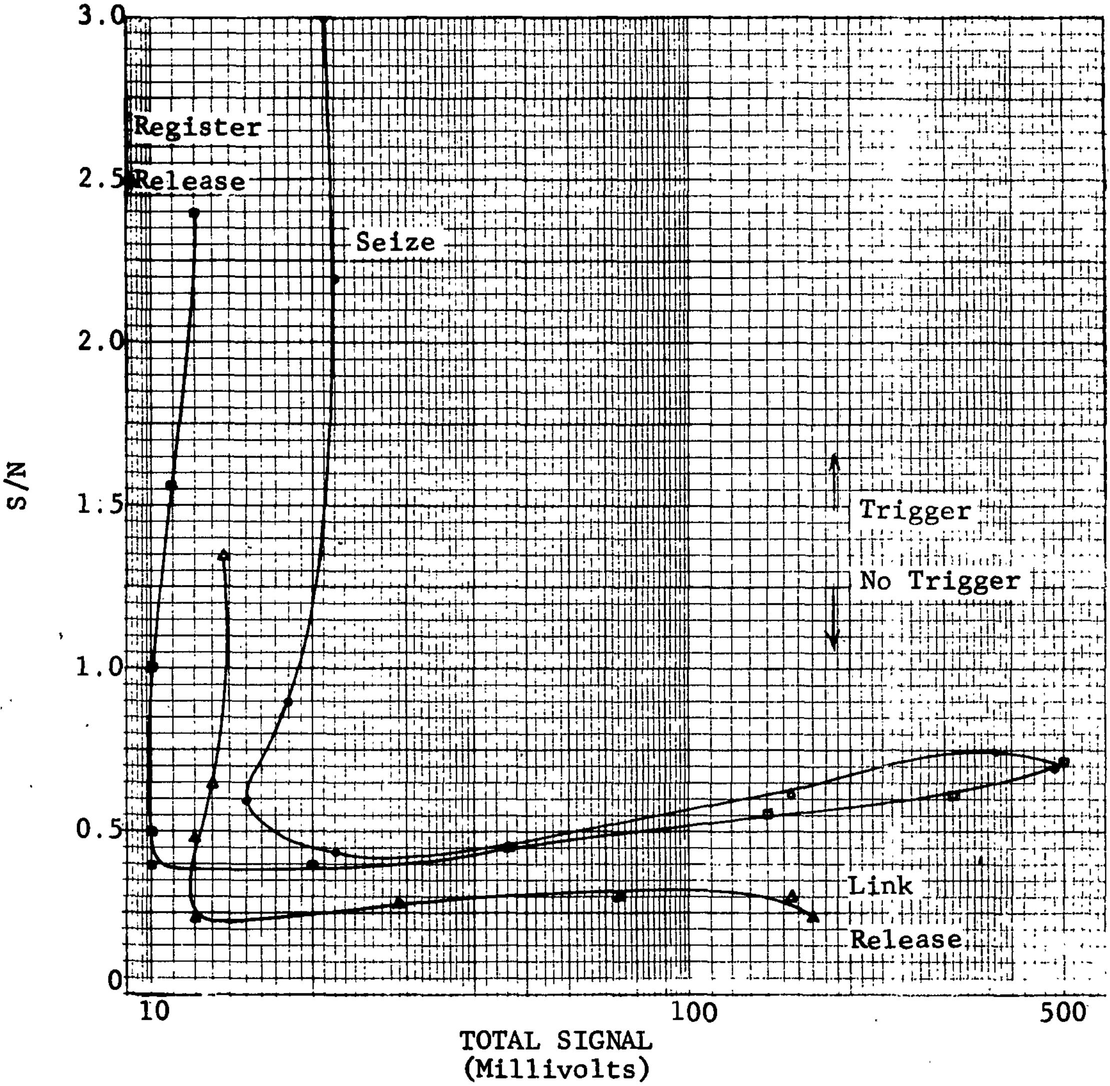


FIGURE B-31

SEIZE, REGISTER RELEASE AND LINK RELEASE
SIGNAL TO NOISE S/N VERSUS TOTAL SIGNAL
AN/TTC-12 SN 1

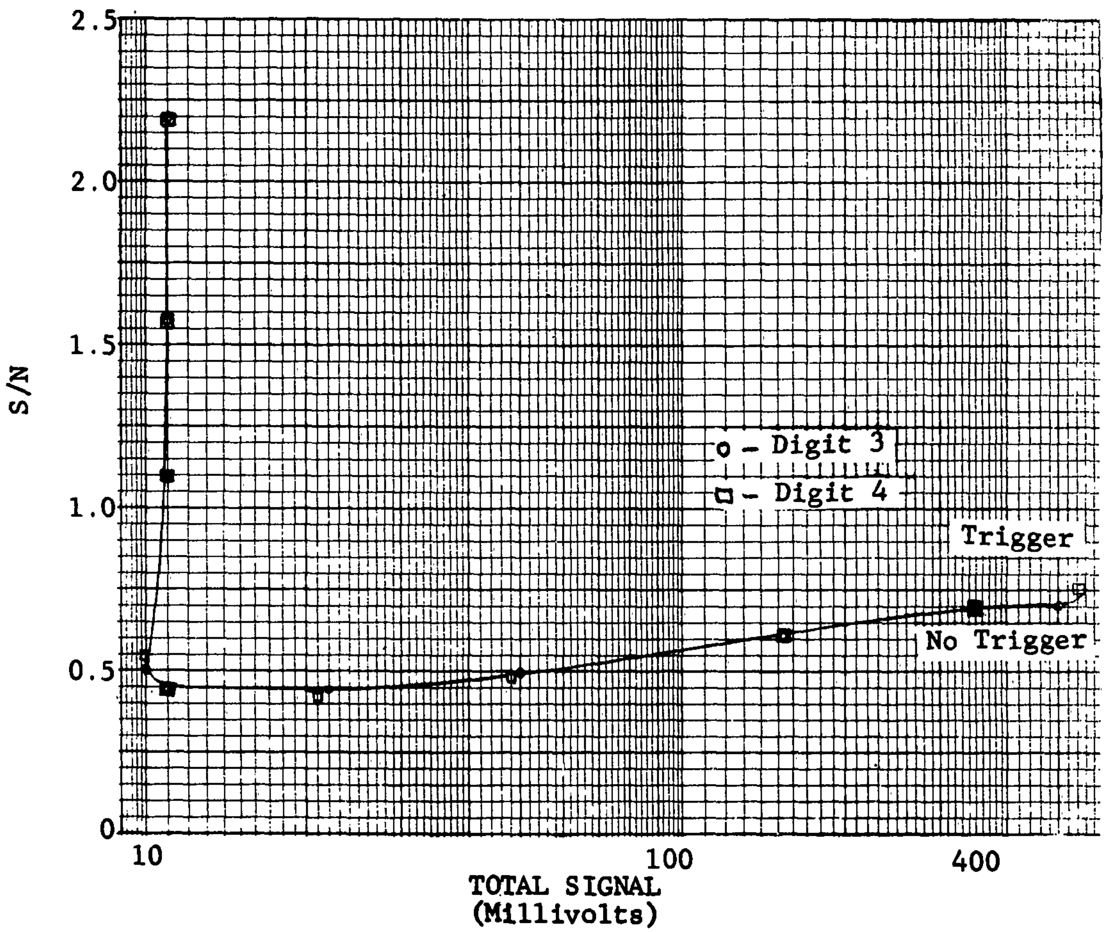


FIGURE B-32

DIGIT 3 AND 4 SIGNAL TO NOISE (S/N) VERSUS TOTAL SIGNAL
AN/TTC-12 SN 3
Subscriber Register No. 1

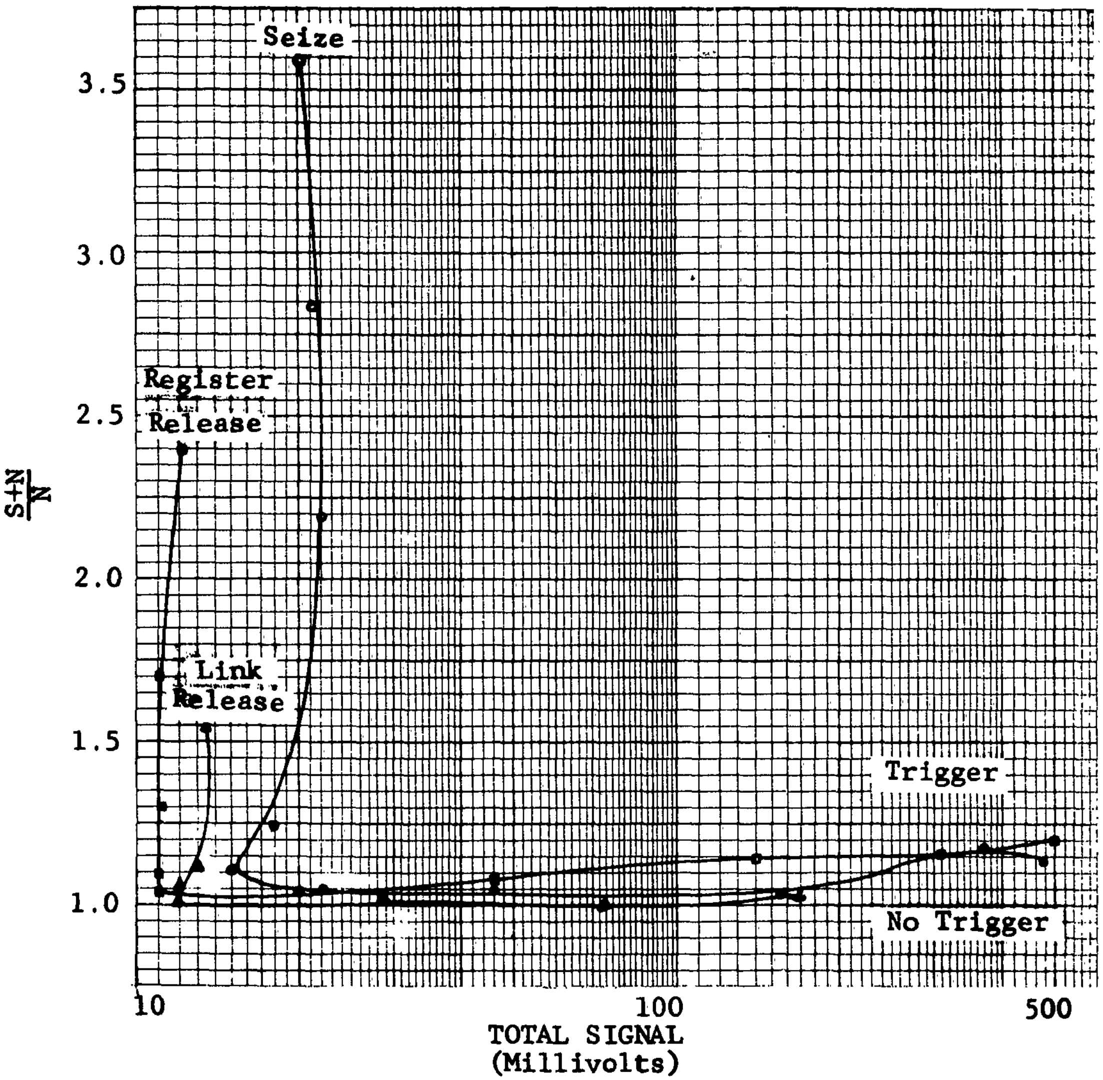


FIGURE B-33

SEIZE, REGISTER RELEASE AND LINK RELEASE
SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-12 SN 3

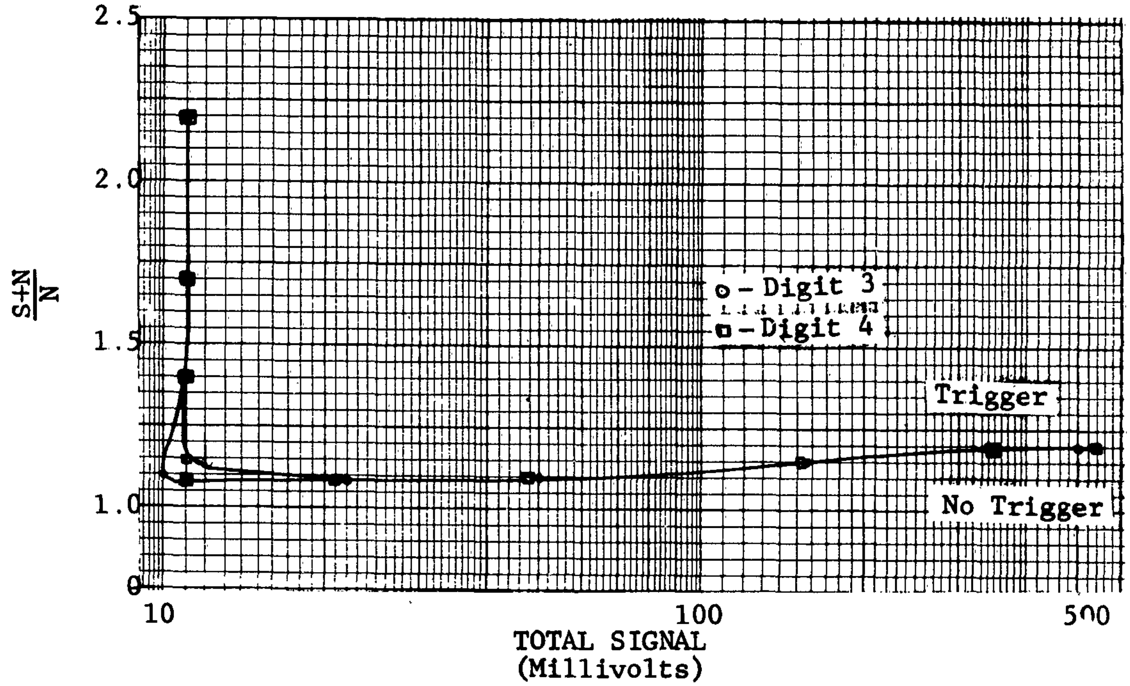


FIGURE B-34

DIGIT 3 AND 4 SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-12 SN 3
Subscriber Register No. 1

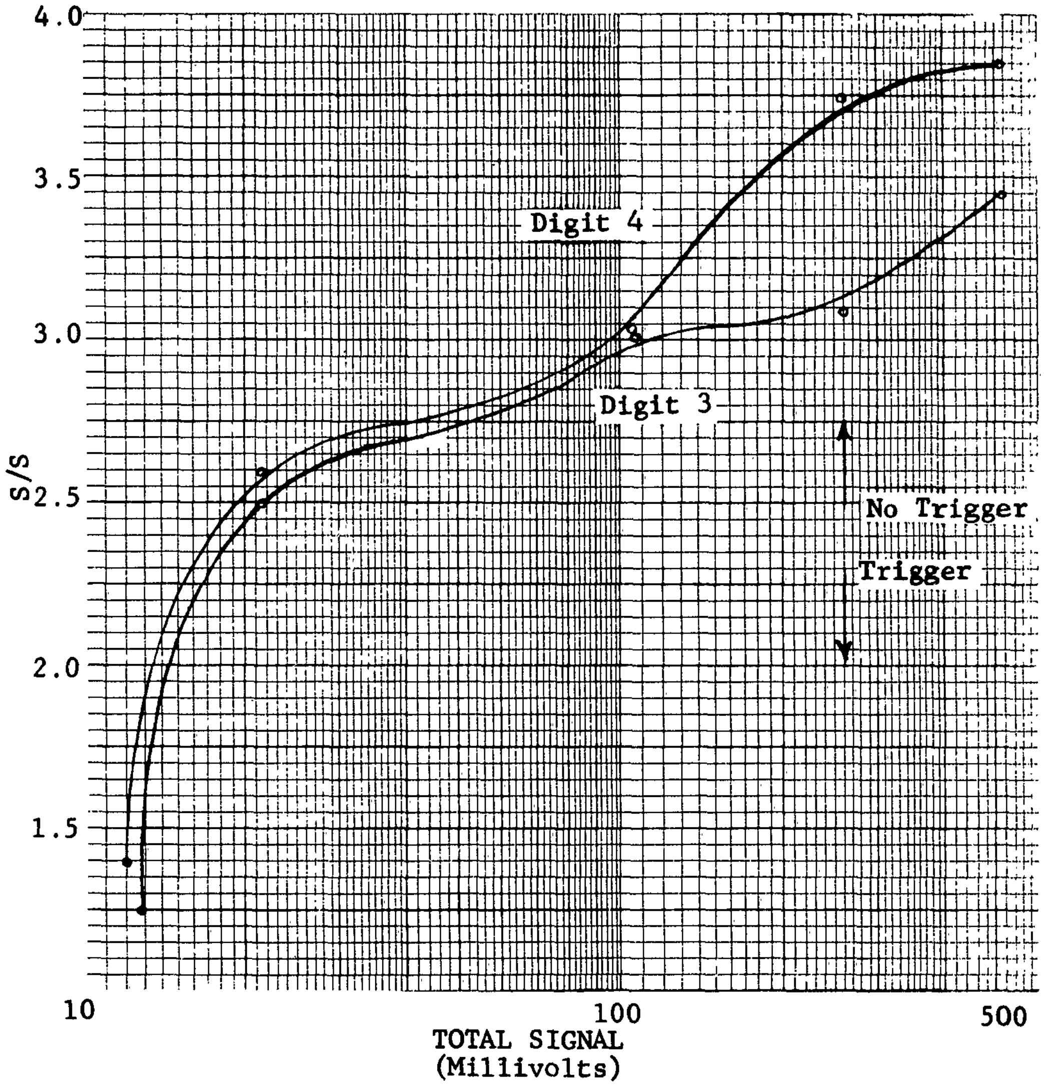


FIGURE B-35

DIGIT 3 AND 4 SIGNAL TO SIGNAL (S/S) VERSUS TOTAL SIGNAL
AN/TTC-12 SN 1
Unmodified Reg. No. 5

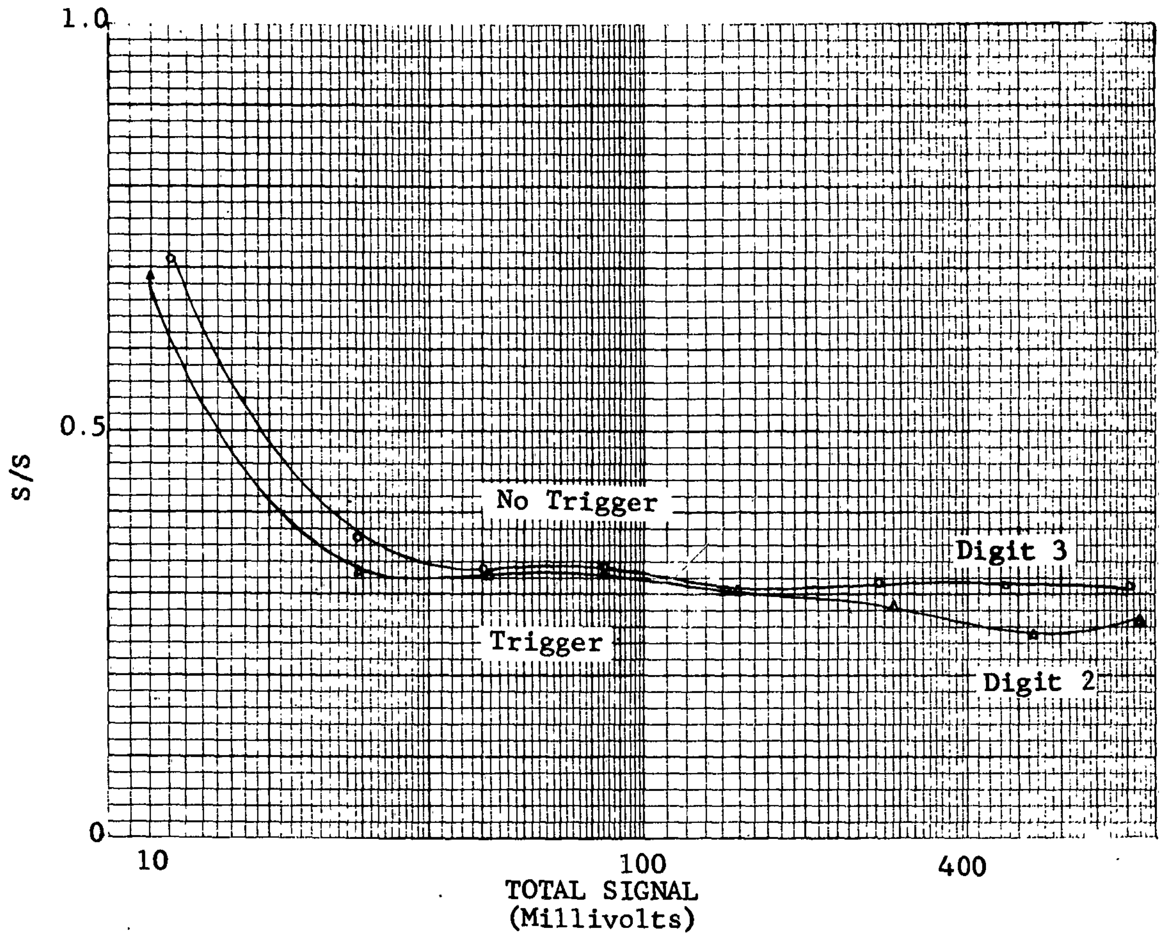


FIGURE B-36

DIGIT 2 AND 3 SIGNAL TO SIGNAL (S/S) VERSUS TOTAL SIGNAL
AN/TTC-12 SN 3

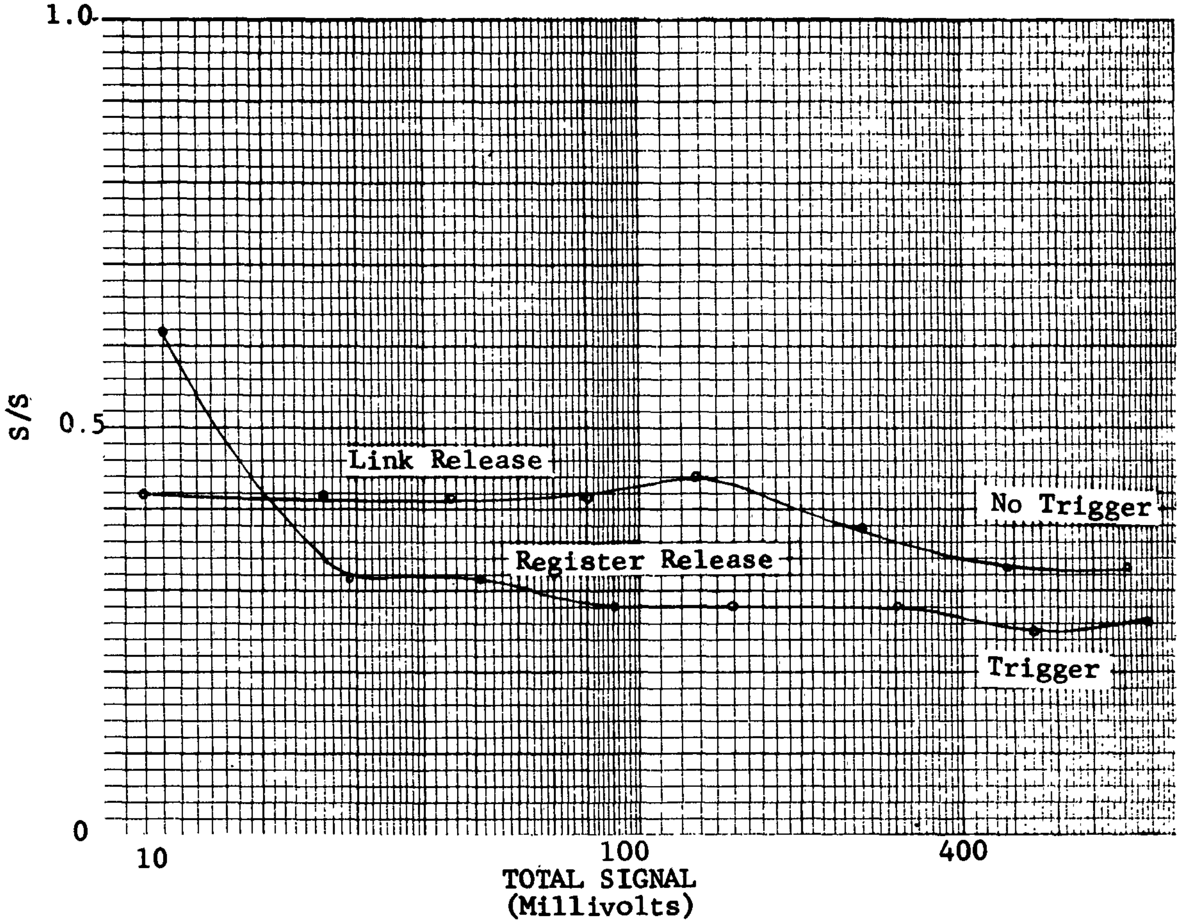


FIGURE B-37

LINK RELEASE AND REGISTER RELEASE
SIGNAL TO SIGNAL (S/S) VERSUS TOTAL SIGNAL
AN/TTC-12 SN 3

The following types of switching operations are performed; (a) switches calls from local boards or tandem boards to other local or tandem boards; (b) switches calls from local or tandem boards to operator's position; (c) switches calls from local or tandem boards to other long distance boards; (d) switches calls from long distance boards to other long distance boards; (e) switches calls from long distance boards to local or tandem boards; (f) switches calls from long distance boards to operator's position.

Calls can be keyed from one local subscriber to another by keying directly through one or more long distance boards or by keying the operator's position and having the operator complete the call.

All digits keyed through a long distance board to another long distance board are interlocking. Thus, a digit is sent from a long distance central to a second long distance central which in turn sends a verification signal allowing the first long distance central to send a second digit.

2.2.3 TECHNICAL DESCRIPTION

(1)	Total line and trunk capacity	164
(2)	Long distance trunks served	100
(3)	Local trunks served	60
(4)	Service lines served	4
(5)	Signalling All signalling is done by single or compound tones.	
(6)	Signalling Code Assignment	

S - 1700 cps	X - 2500 cps
U - 1900 cps	Y - 2700 cps
V - 2100 cps	Z - 2900 cps
W - 2300 cps	

Digital Signals

1 - VW	6 - YW
2 - XW	7 - VX
3 - UY	8 - UW
4 - UV	9 - VY
5 - XY	0 - UX

Dial Tone - 600 cps
Ring Signal - 600/20 cps (1 sec on, 2 sec off)
Busy Tone (line) - 600 cps (1/2 sec on, 1/2 sec off)

Busy Tone (trunk) - 600 cps (1/4 sec on, 1/4 sec off)
Ring Back Tone - 600 cps (1 sec on, 2 sec off)
Signal Duration for Detection-50 msec

(7) Channel Transmission Characteristics

Transmission - time division multiplexing

One frame period (32 time slots)	80	μ sec
One time slot	2.5	μ sec
Sampling time	1.25	μ sec
Guard time	1.25	μ sec
Frame repetition frequency	12.5	KC

(8) Power Requirements

Input voltage - 110 volt 60 cps single phase
Input current (total) - 19.2 amps

2.2.4 TEST RESULTS - AN/TTC-13

2.2.4.1 INPUT IMPEDANCE

Input impedance measurements were made on random trunk to trunk combinations of the AN/TTC-13 SN 1. A plot of the most probable mean of the input impedance versus frequency and the range defining the limits of excursion of sample means with a 95 per cent confidence level is shown in Figure B-38. The input impedance varied from a minimum of 554 ohms at 300 cps to a maximum of 678 ohms at 2400 cps. The phase angle of the impedance did not exceed 15.8 degrees.

2.2.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on random trunk to trunk combinations of the AN/TTC-13 SN 1. A plot of the most probable mean of the output impedance versus frequency and the range defining the limits of excursion of the sample means with a 95 per cent confidence level is shown in Figure B-39. The output impedance varied from a minimum of 577 ohms at 300 cps to a maximum of 661 ohms at 3800 cps. The phase angle of the impedance did not exceed 22.5 degrees.

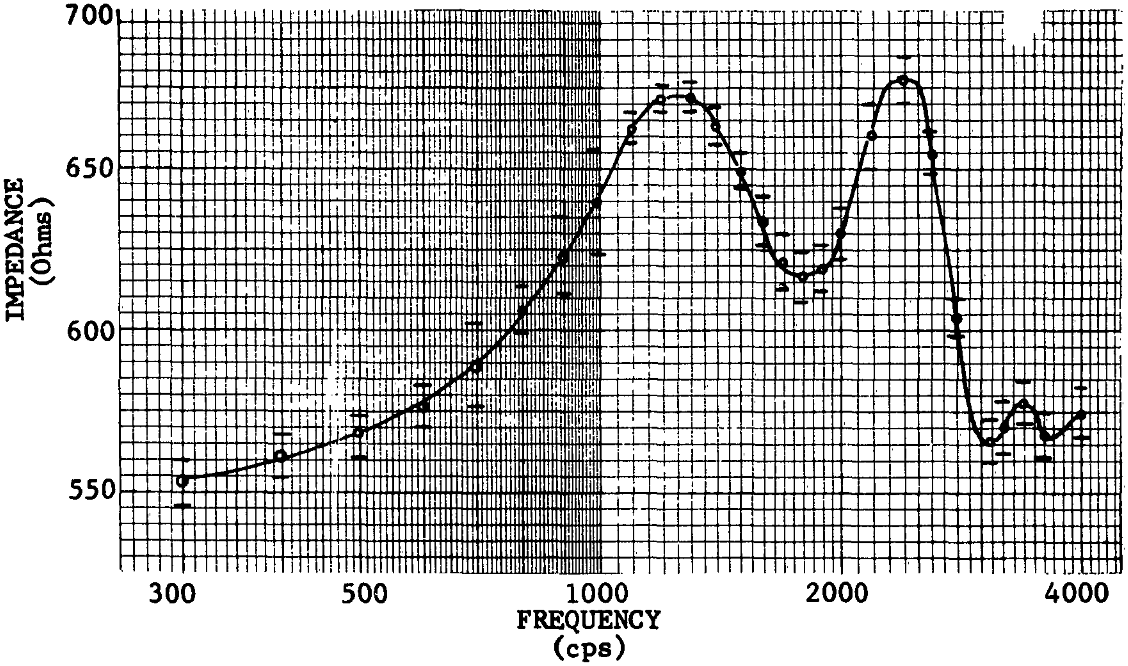


FIGURE B-38

INPUT IMPEDANCE - AN/TTC-13 SN 1
Statistically Derived

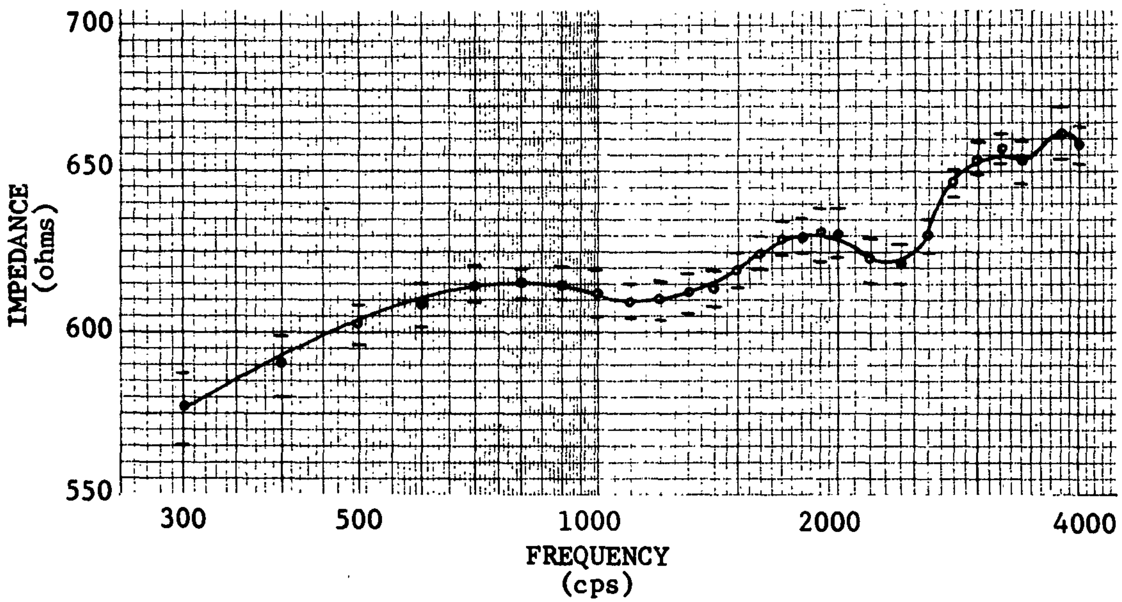


FIGURE B-39

OUTPUT IMPEDANCE - AN/TTC-13 SN 1
Statistically Derived

2.2.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on random trunk to trunk combinations of the AN/TTC-13 SN 1 using an input signal level of -4 dbm. The response was flat (± 0.98 db) from 300 to 3500 cps. The insertion loss at 1000 cps was + 0.13 db. A plot of the frequency response is shown in Figure B-40. Since the average range of the excursion of the means for a 95 per cent confidence level was only 0.005 db, the range was not shown in the figure.

2.2.4.4 CROSSTALK LOSS

Measurements were made of the near end and far end crosstalk loss on random trunk combinations of the AN/TTC-13 SN 1 using two internal routings through the switching centrals; namely, same time slot - adjacent highway, and adjacent time slot - same highway. Figures B-41 and B-42 show the most probable mean of the crosstalk loss for these two types of internal routings. The statistical range of excursion of the means for a 95 per cent confidence level was well under 1 db. Therefore, the range was not plotted on the figures.

2.2.4.5 HARMONIC DISTORTION

Harmonic distortion measurements were made on random trunk to trunk combinations of the AN/TTC-13 SN 1. A plot of the most probable mean of the total per cent harmonic distortion is shown in Figure B-43. The range of excursion of the means for a 95 per cent confidence level was within the accuracy of the test equipment (0.2%) and therefore is not plotted.

2.2.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on random trunk to trunk combinations of the AN/TTC-13 SN 1. A pair of fundamental frequencies (f_1 and f_2) separated by 200 cps and producing a total input signal level of -4 dbm were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$), cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$), and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distortion products falling within the equipment passband were measured for each frequency pair as shown in Figure B-44. All distortion products were found to be more than 40 db down from the individual fundamentals.

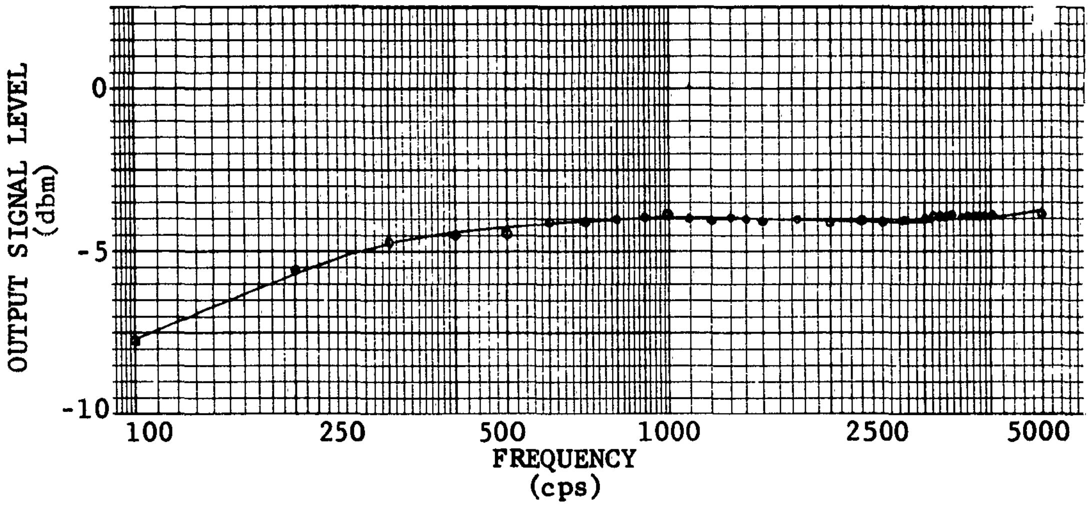


FIGURE B-40

FREQUENCY RESPONSE - AN/TTC-13 SN 1
Statistically Derived
Input Level -4 dbm

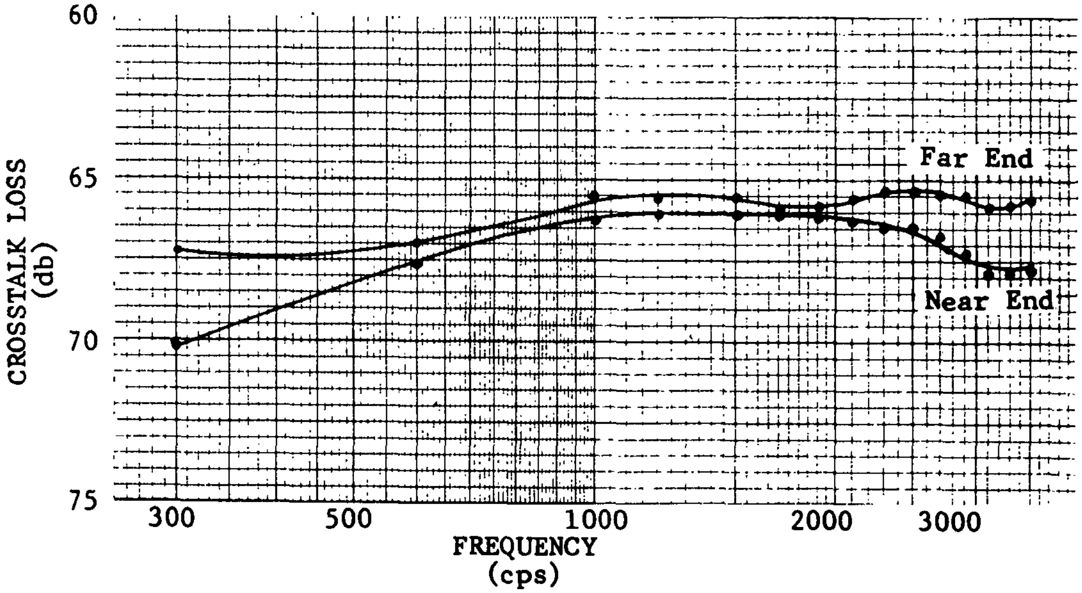


FIGURE B-41

CROSSTALK LOSS - AN/TTC-13 SN 1
SAME HIGHWAY - ADJACENT TIME SLOT
Statistically Derived
Input Level -4 dbm

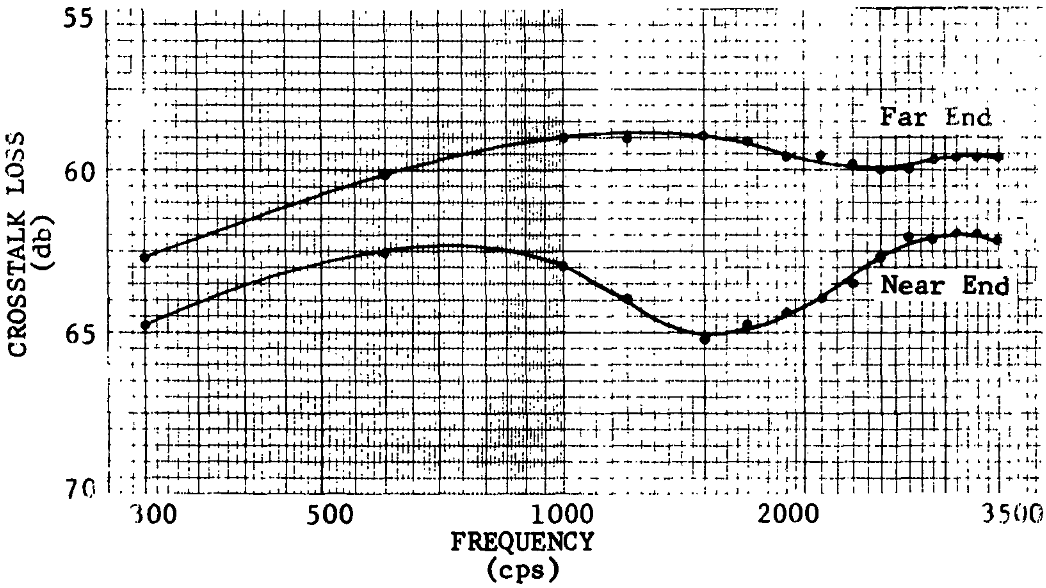


FIGURE B-42

CROSSTALK LOSS - AN/TTC-13 SN 1
SAME TIME SLOT - ADJACENT HIGHWAY
Statistically Derived
Input Level -4 dbm

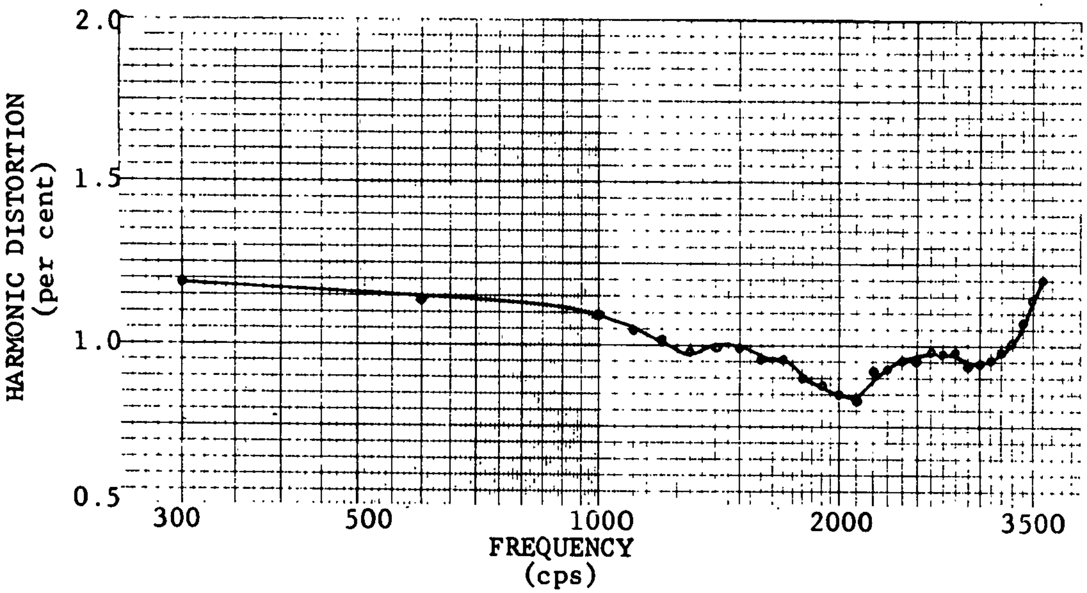
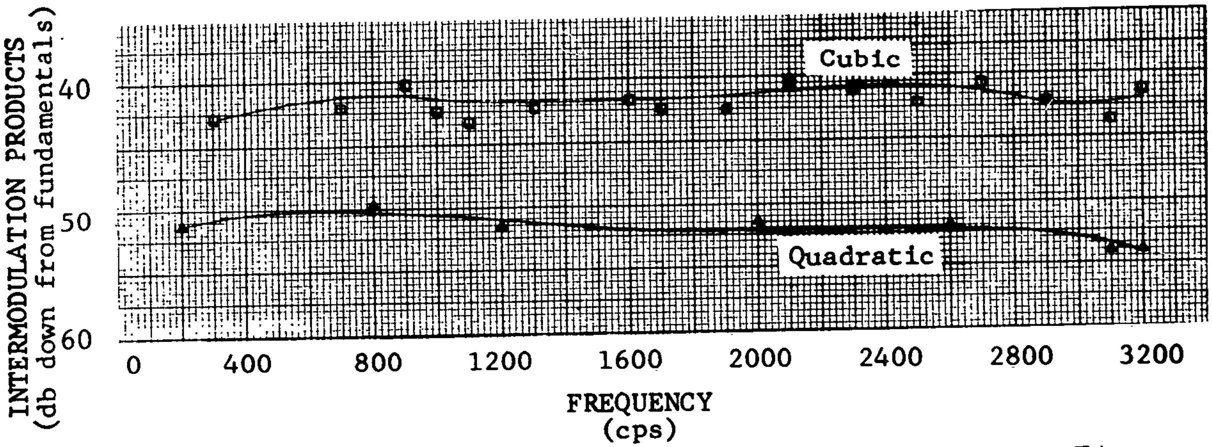


FIGURE B-43

HARMONIC DISTORTION - AN/TTC-13 SN 1
Statistically Derived
Input Level -4 dbm



Frequency Pairs

300-500
500-700
900-1100
1200-1400
1500-1700
1250-1875
1900-2100
2300-2500
2500-2700
2900-3100

FIGURE B-44

INTERMODULATION DISTORTION - AN/TTC-13 SN 1
Input Level -4 dbm (total)

2.2.4.7 NOISE

Noise measurements, taken on 10 random trunks of AN/TTC-13 SN 1, showed the noise level to be below 17 dba (-68 dbm), the sensitivity of the instrumentation described in the test procedures of Annex A.

2.2.4.8 PHASE DISTORTION

The envelope delay time was measured on random trunk to trunk combinations of the AN/TTC-13 SN 1 using an input signal level of -4 dbm. A plot of the envelope delay time versus frequency is shown in Figure B-45. Due to instrumentation available (reference paragraph 2.1.4.8) precise data could not be obtained.

Figure B-46 shows a plot of the arithmetic mean of a sample containing 9 trunk/trunk combinations. This curve is presented as an aid to the interpretation of the envelope delay plot of Figure B-45.

2.2.4.9 LONGITUDINAL BALANCE

The longitudinal balance was measured on AN/TTC-13 SN 1. The balance between 10 randomly selected trunk to trunk combinations and ground using randomly selected links and trunk groups averaged more than 73 db below the reference signal level. The data obtained is tabulated in Table B-15.

2.2.4.10 LIMITING

Limiting was measured on random trunk to trunk combinations of AN/TTC-13 SN 1. A plot of the most probable mean of limiting over the range of input levels from -8 to +12 dbm is shown in Figure B-47. Absolute limiting is observed to occur at +4 dbm output level. The statistical range of excursion of the means was under 0.2 db, hence was not plotted on the figure.

2.2.4.11 CARRIER LEVEL

The level of the 12.5 Kcps carrier (TDM sampling rate) was measured on random trunk to trunk combinations on AN/TTC-13 SN 1. Table B-16 presents a tabulation of carrier levels measured on 10 trunk/trunk combinations. All lines tested showed carrier levels to be lower than -60 dbm.

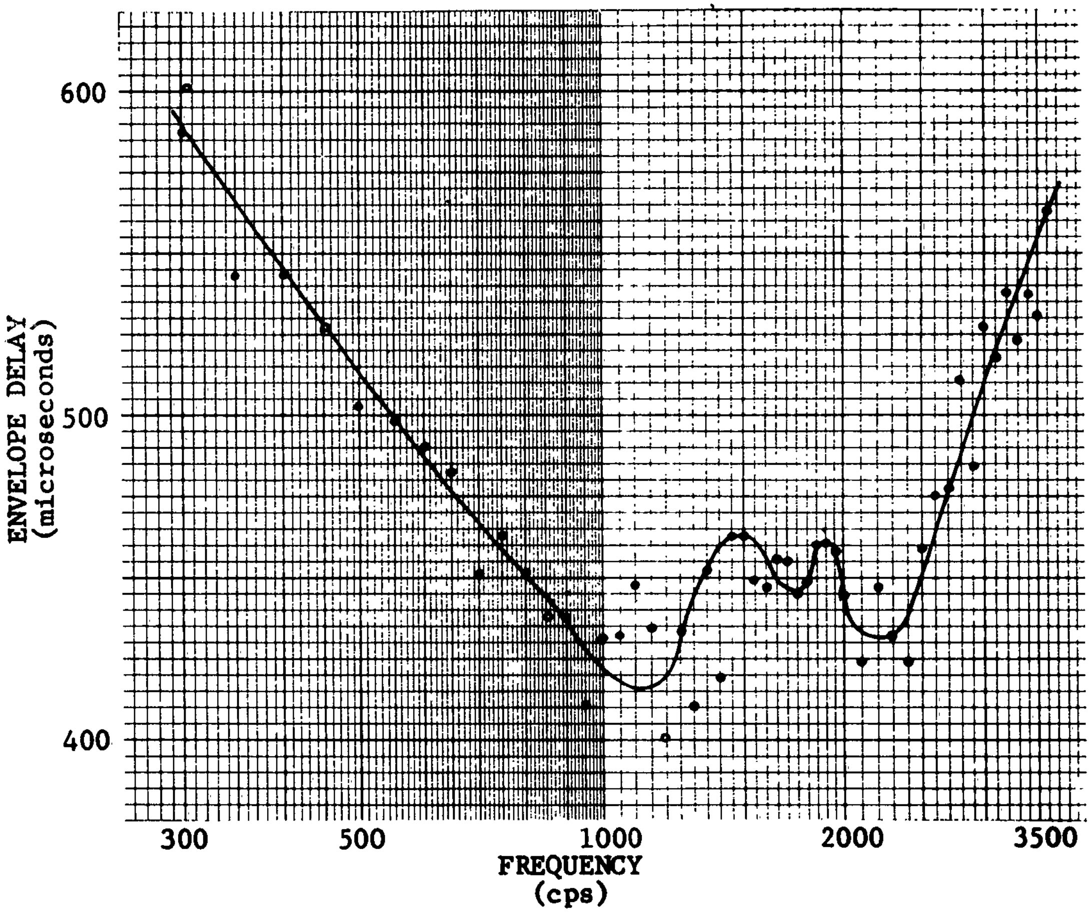


FIGURE B-45

ENVELOPE DELAY - AN/TTC-13 SN 1
Lines Tested 9
Input Level -4 dbm

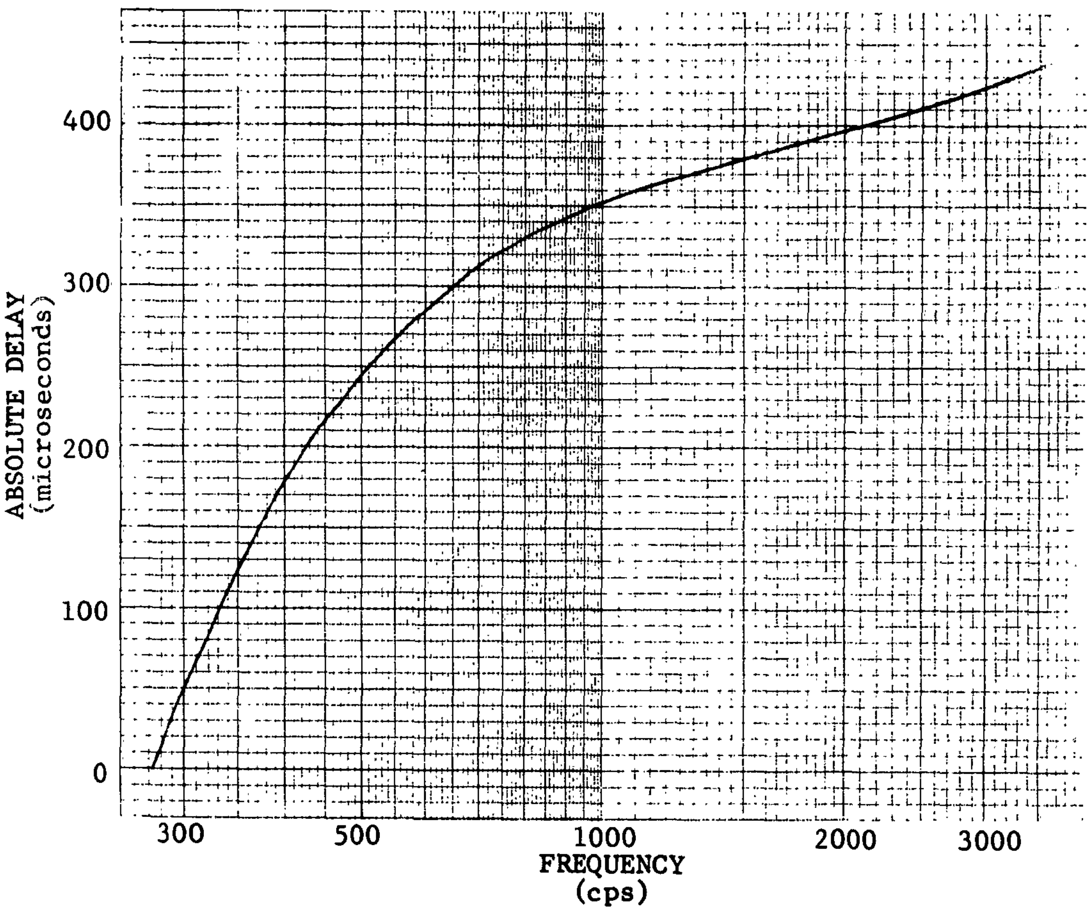


FIGURE B-46

ABSOLUTE DELAY - AN/TTC-13 SN 1
Lines Tested 9
Input Level -4 dbm

TABLE B-15

LONGITUDINAL BALANCE - AN/TTC-13 SN 1

Local Trunk	Long Distance Trunk	Link	Trunk	Longitudinal Balance in Decibels
3	42	77	6	73.2
59	18	4	7	76.3
43	25	29	9	72.6
13	98	14	9	72.0
12	61	36	8	71.7
21	42	21	8	Not Readable
46	33	54	3	76.3
11	2	48	6	72.5
13	87	9	4	75.8
26	19	61	5	72.7

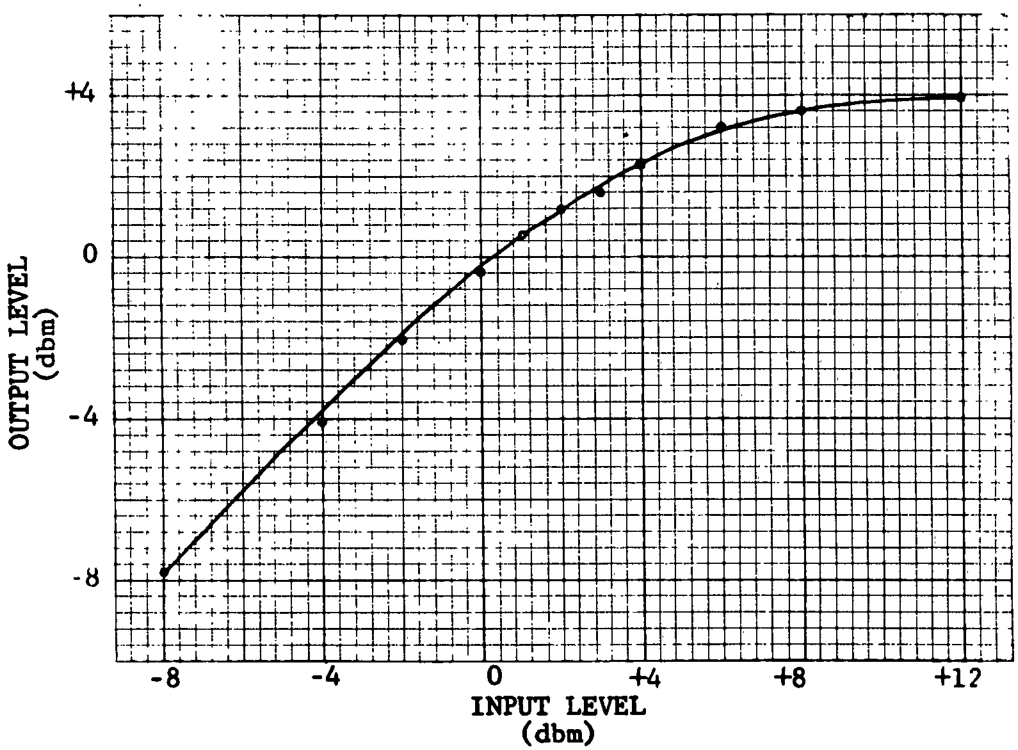


FIGURE B-47

LIMITING - AN/TTC-13 SN 1
Statistically
Derived

TABLE B-16

CARRIER LEVEL - AN/TTC-13 SN 1
(TDM Sampling Frequency 12.5 Kcps)

LOCAL TRUNK	LONG DISTANCE TRUNK	LINK	TRUNK GROUP	CARRIER LEVEL (dbm)
2	32	43	2	-62.8
38	69	4	4	-72.0
57	79	46	7	-60.7
22	44	31	9	-60.7
9	15	36	8	-58.5
27	99	35	2	-65.8
14	15	57	4	-57.2
53	81	55	6	-64.4
10	9	53	9	-65.5

Carrier levels were not measured for the 400 Kcps master clock frequency due to the unavailability of RF wave analyzer equipment.

2.2.4.12 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits in the AN/TTC-13 SN 1. Plots of the selectivity and sensitivity are shown in Figures B-48 through B-57. The sensitivities of the detectors range from -24 to -42 dbm.

The routine test circuit was not functioning properly at the time of testing; therefore, the tone detectors associated with this circuit were not tested.

The sensitivity and selectivity of the 600 cycle detector of circuit 1 of the Terminating Detector - Direct Dial Register differed markedly from the other 600 cycle detectors of this register as shown in Figure B-55.

2.2.4.13 TONE GENERATOR OUTPUT

The frequency and power output of the several tone generators of AN/TTC-13 SN 1 were measured. The data obtained, measured at the output terminal of the central, are tabulated in Tables B-17 through B-20.

2.2.4.14 SIGNAL TO NOISE AND SIGNAL PLUS NOISE TO NOISE

Signal to noise and signal plus noise versus total signal ratios were measured on the AN/TTC-13 SN 1. Plots showing the effect of noise upon the sensitivity of detector circuitry are shown in Figures B-58 through B-60.

Because this unit is used with a no loss carrier system signal/signal ratio would remain at 1.0. Therefore, signal to signal ratio versus total signal were not measured.

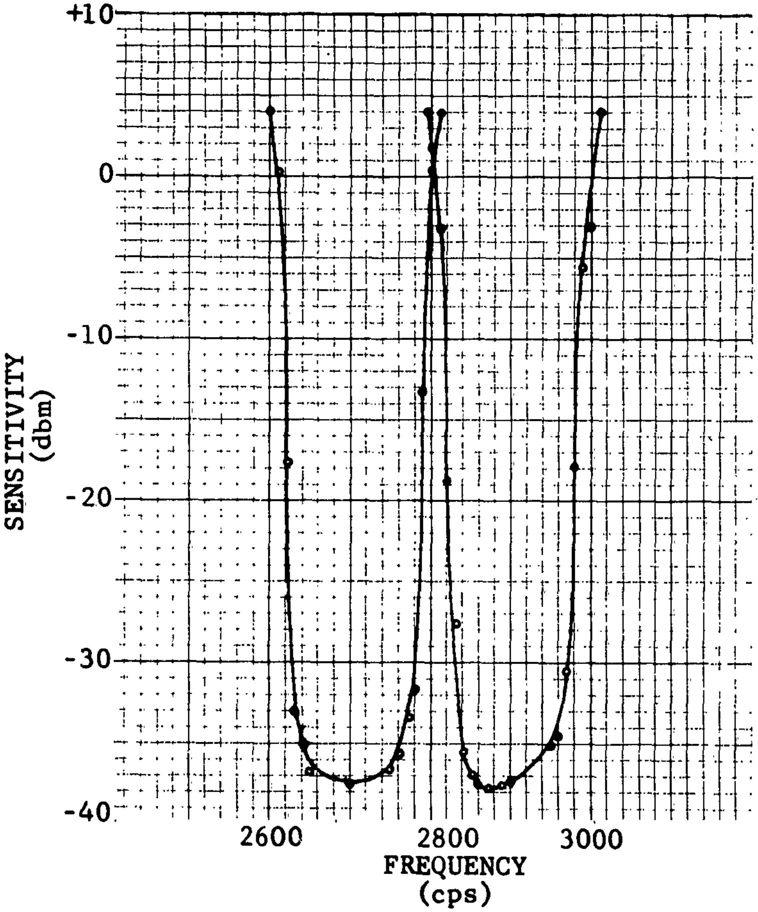


FIGURE B-48

RELEASE DETECTOR SELECTIVITY CURVES
AN/TTC-13 SN 1

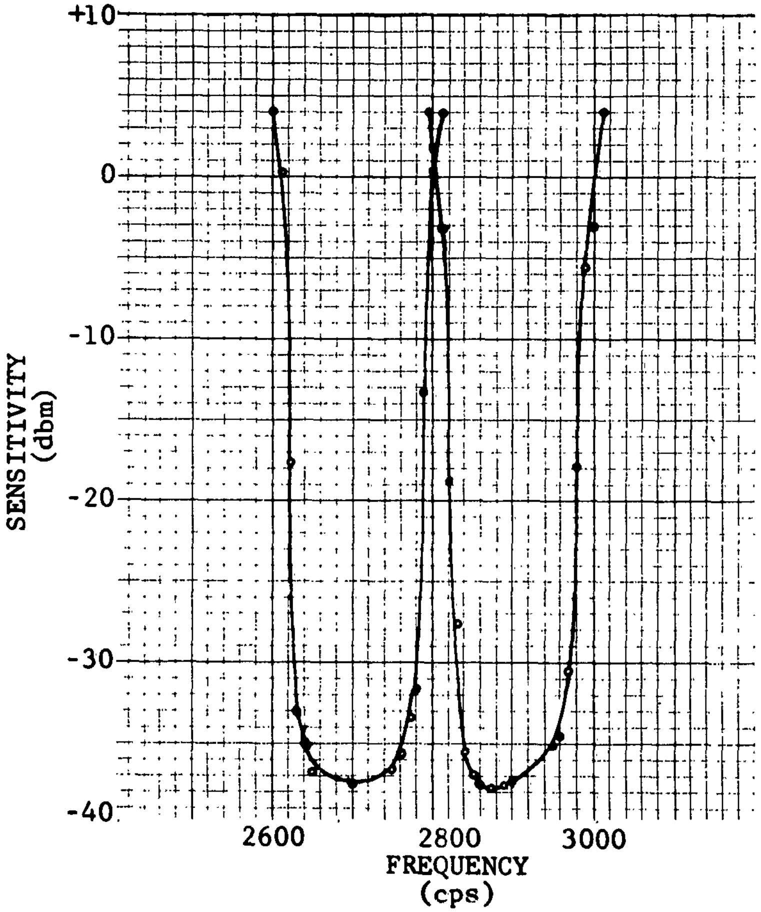


FIGURE B-48

RELEASE DETECTOR SELECTIVITY CURVES
AN/TTC-13 SN 1

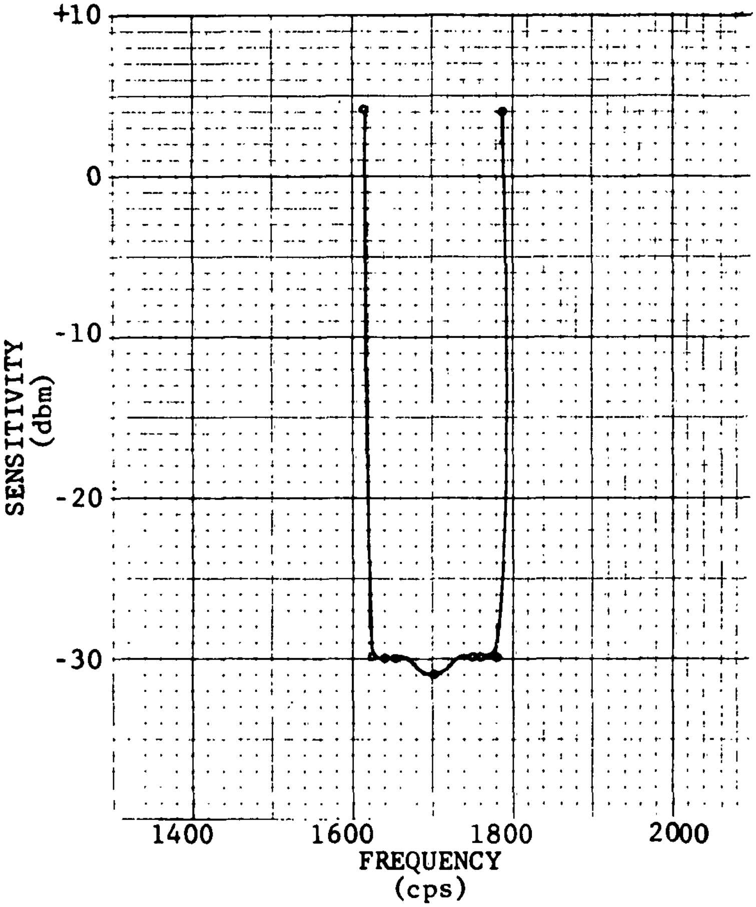


FIGURE B-49

SEIZE DETECTOR SELECTIVITY CURVES
AN/TTC-13 SN 1

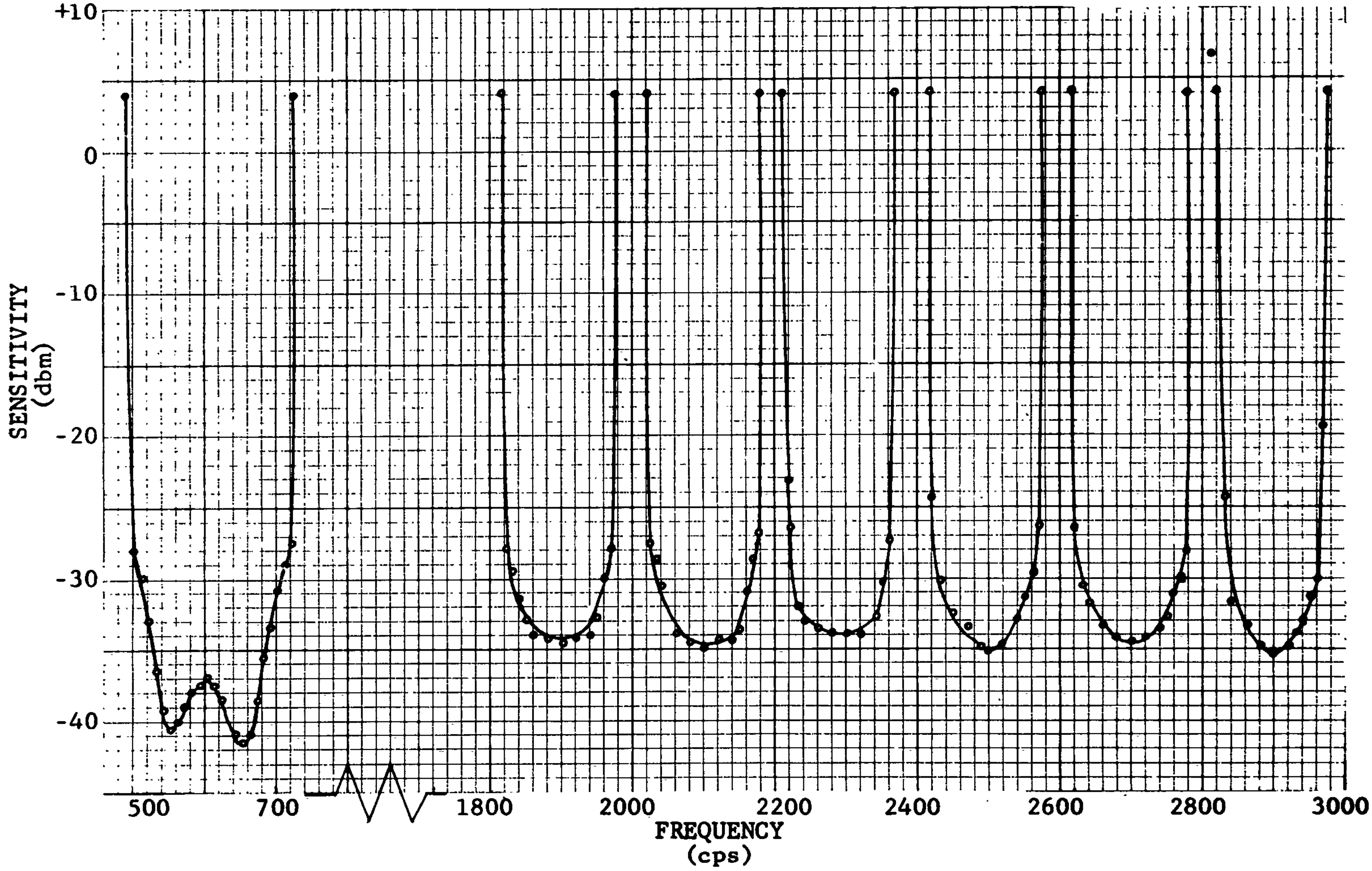


FIGURE B-50

POSITION REGISTER SELECTIVITY CURVES
AN/TTC-13 SN 1

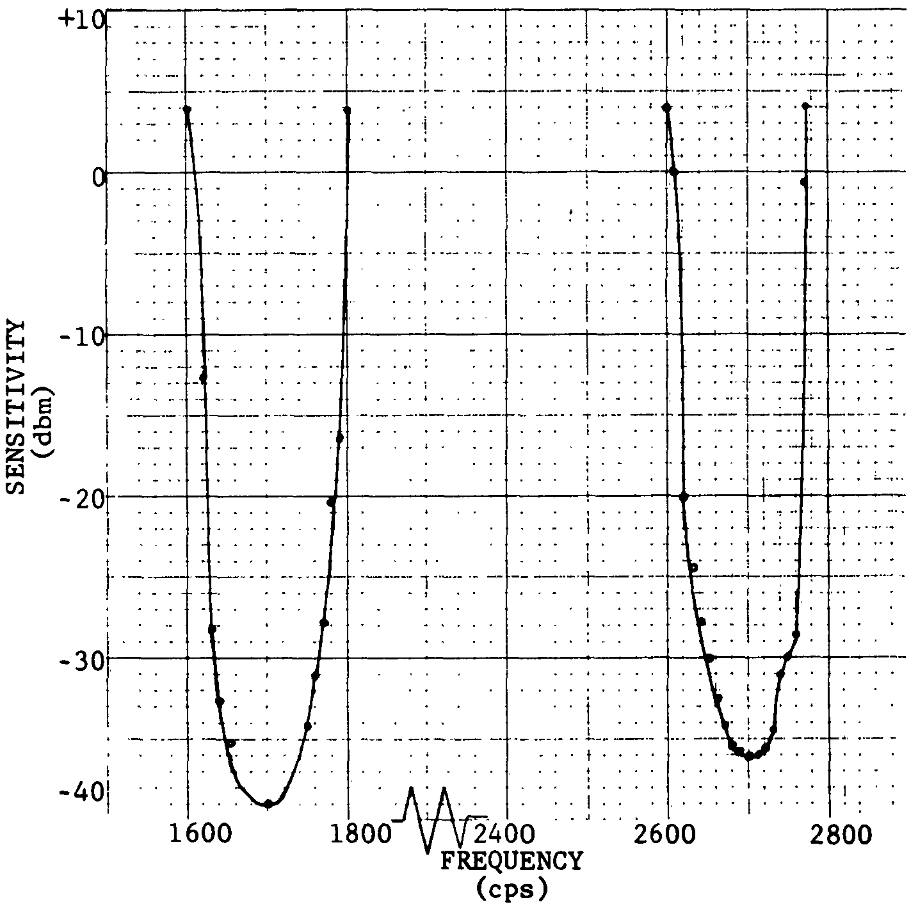


FIGURE B-51

ROUTE SELECTOR MFSD SELECTIVITY CURVES
AN/TTC-13 SN 1

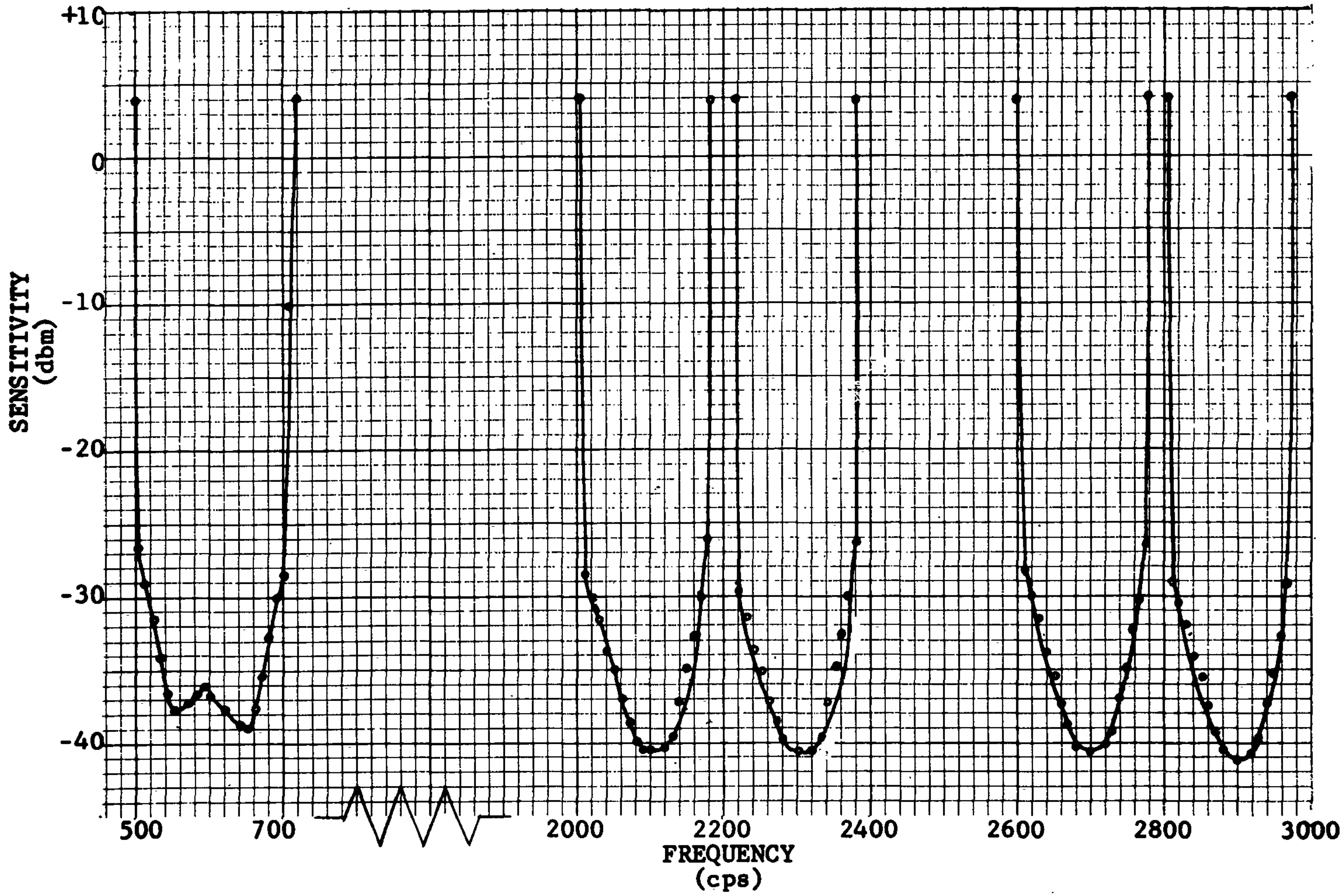


FIGURE B-52

TEST TONE ANSWERING CIRCUIT SELECTIVITY CURVES
AN/TTC-13 SN 1

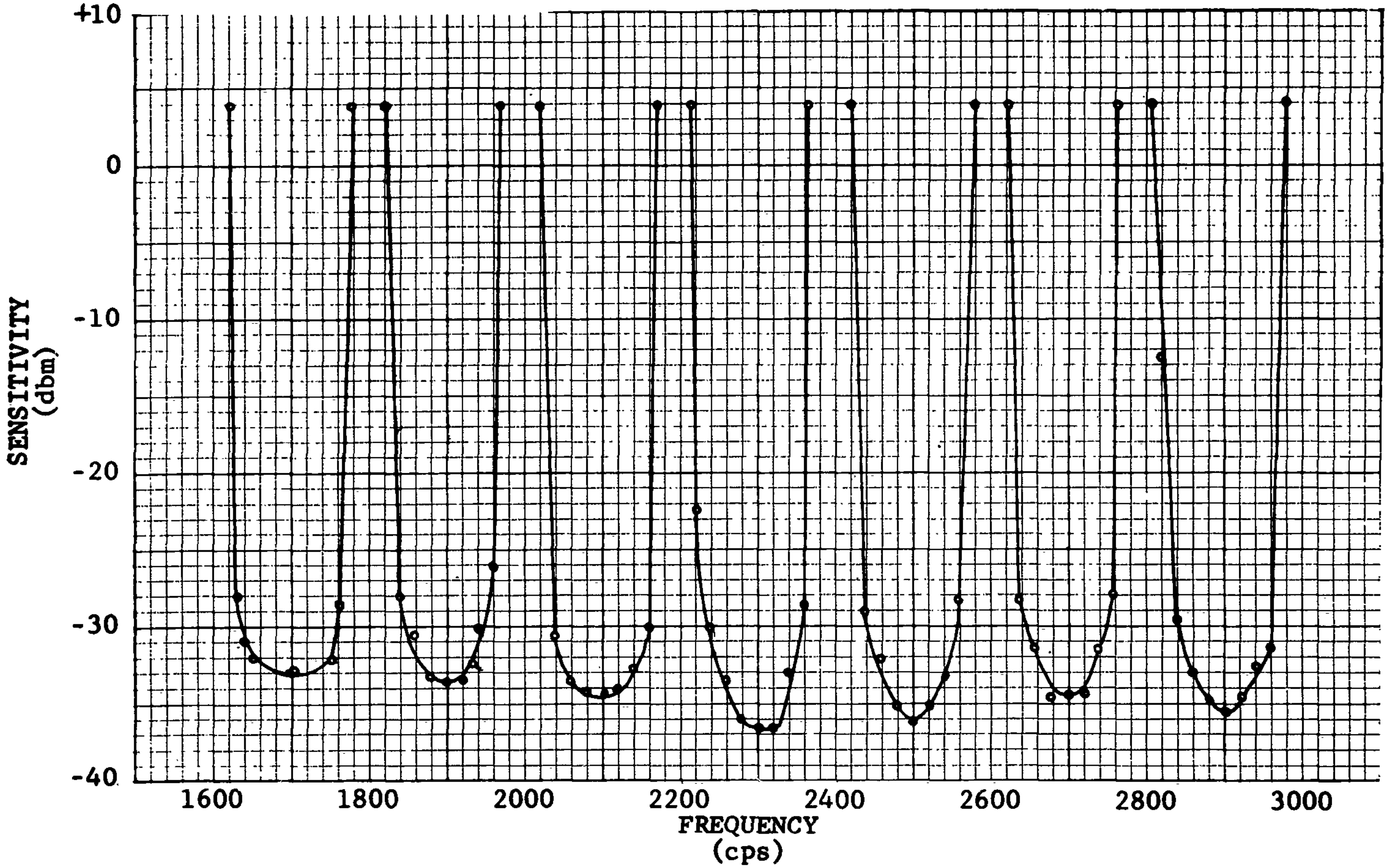


FIGURE B-53

INTERCONNECT REGISTER SELECTIVITY CURVES
AN/TTC-13 SN 1

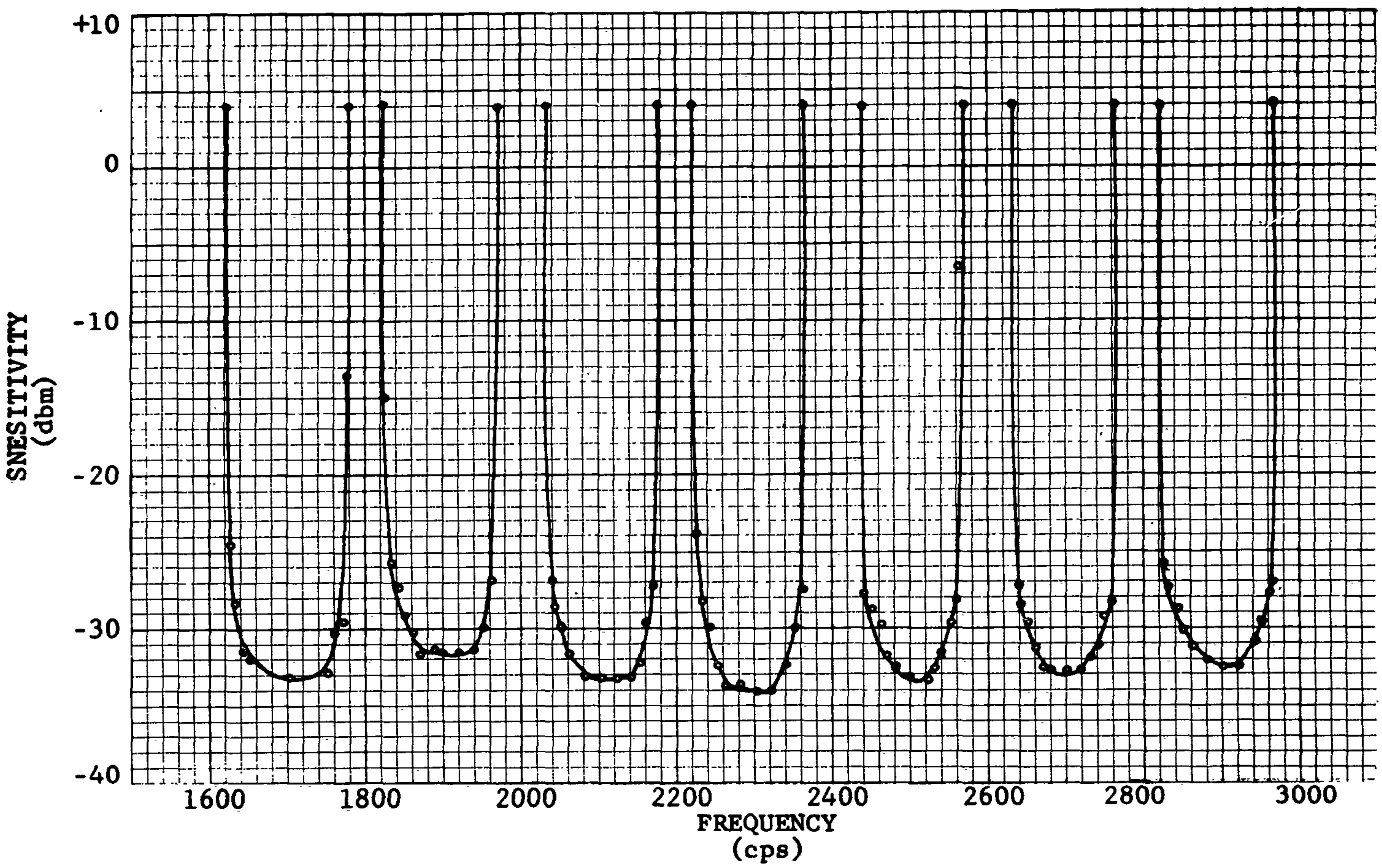


FIGURE B-54

INPUT DETECTORS - DIRECT DIAL REGISTER SELECTIVITY CURVES
AN/TTC-13 SN 1

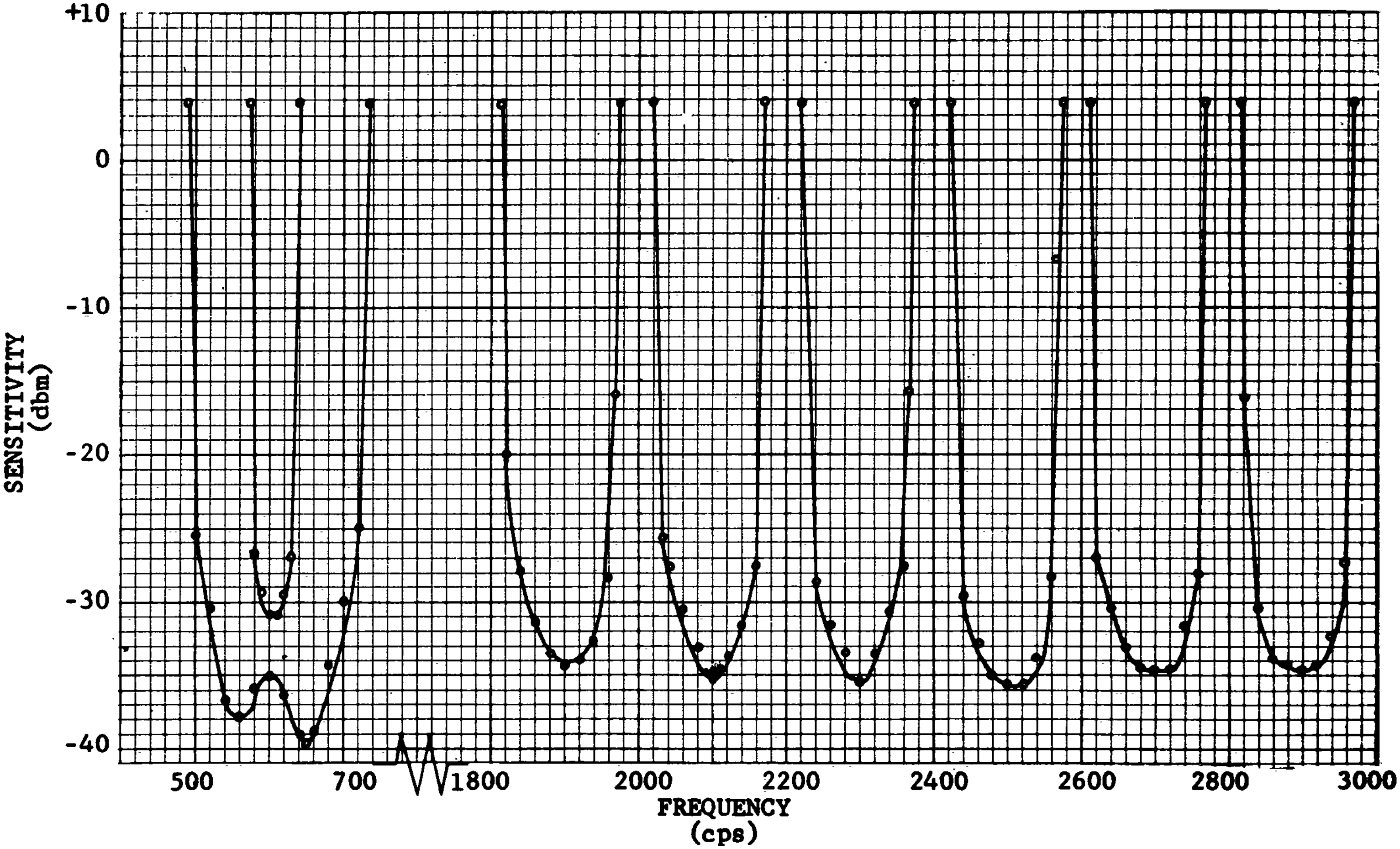


FIGURE B-55

TERMINATING DETECTOR DIRECT DIAL REGISTER SELECTIVITY CURVES
AN/TTC-13 SN 1

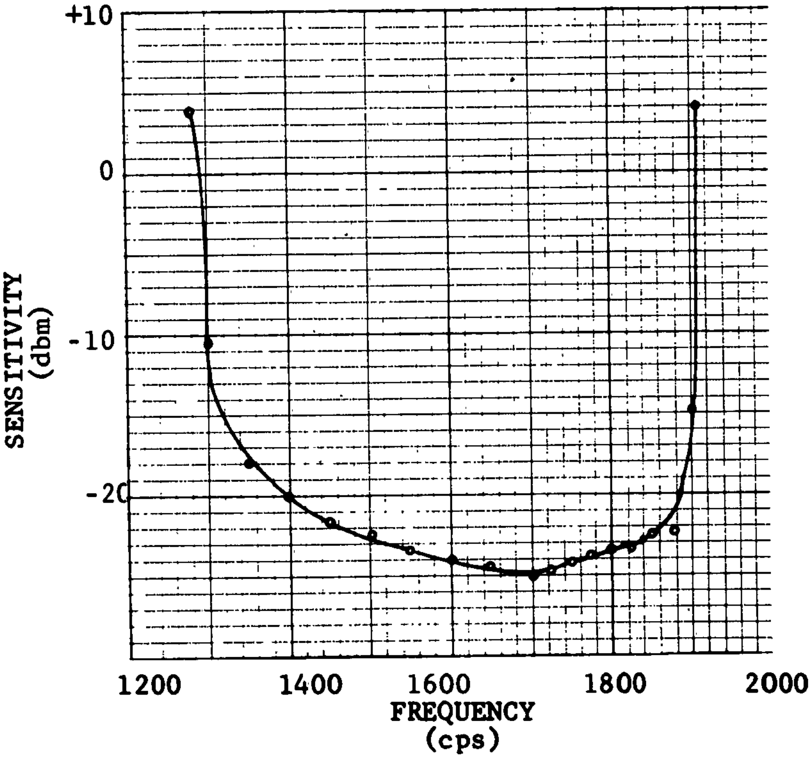


FIGURE B-56

RING TRIP DETECTOR SELECTIVITY CURVE
AN/TTC-12 SN 1

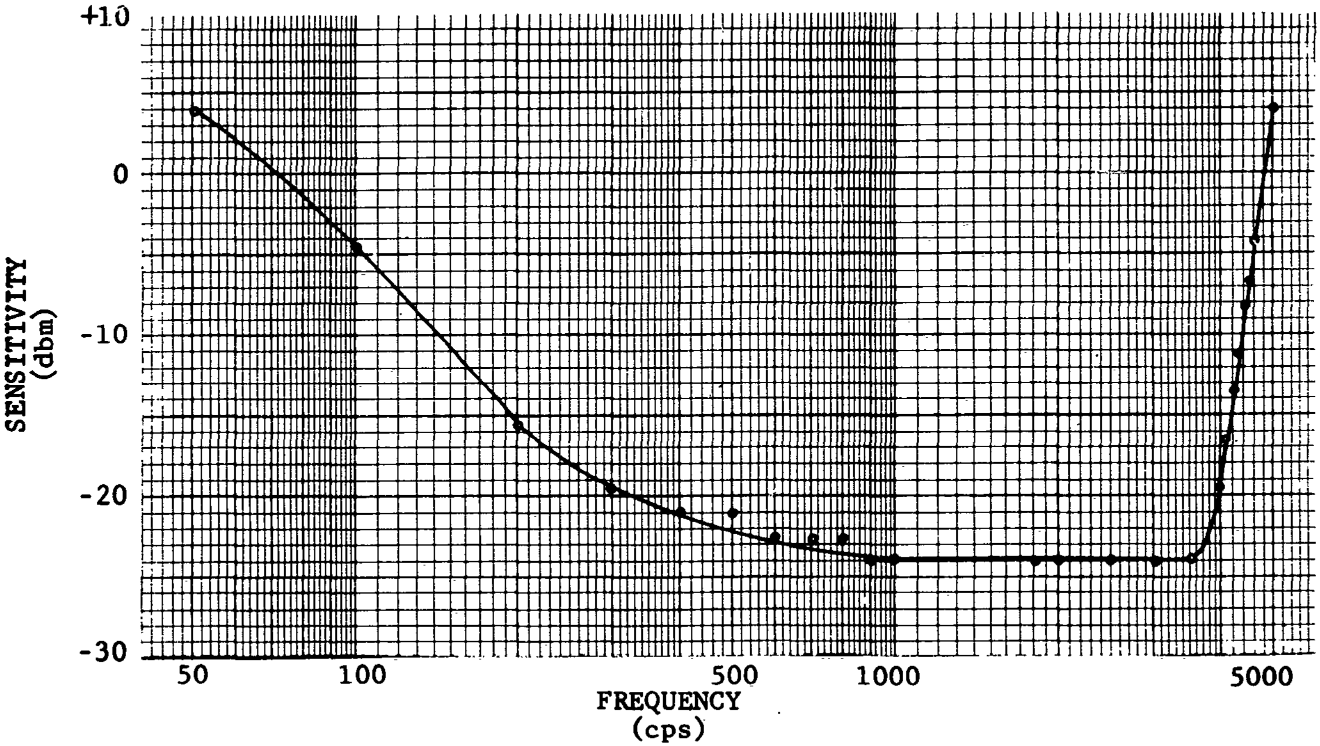


FIGURE B-57

VOICE MONITOR SELECTIVITY CURVE
AN/TTC-13 SN 1

TABLE B-17

TONE GENERATOR OUTPUT AN/TTC-13 SN 1
(DIRECT DIAL REGISTER)

Tone Generator	Frequency	Output Signal Level (dbm) Register No. 1	Register No. 2	Register No. 3
600	608	-19.0	-18.4	-17.7
1700	1704	-13.6	-14.8	-15.0
1900	1905	-17.8	-15.5	-15.3
2100	2105	-18.3	-16.2	-15.8
2300	2304	-18.7	-16.3	-15.7
2500	2505	-18.2	-16.6	-16.8
Ring Forward	---	+ 2.3	+ 1.4	+ 1.4
Ring Back	---	-29.9	-30.0	-30.0

TABLE B-18

TONE GENERATOR OUTPUT AN/TTC-13 SN 1
(POSITION REGISTERS)

Tone Generator	Output Signal Level (dbm) Pos. Reg. No. 1	Output Signal Level (dbm) Pos. Reg. No. 2
1700	-13.9	-14.3
1900	-16.5	-16.3
2100	-16.0	-16.0
2300	-17.0	-16.8
2500	-17.2	-17.0
2700	-17.2	-17.5
2900	-15.6	-16.0

TABLE B-19

TONE GENERATOR OUTPUT AN/TTC-13 SN 1
(I. C. REGISTER)

Tone Generator	Output Signal Level (dbm) Reg.No. 1	Reg.No.2	Reg.No.3	Reg.No.4
1900	-18.5	-16.5	-18.6	-18.2
2100	-18.9	-19.0	-19.5	-18.8
2300	-18.7	-18.5	-18.9	-18.7
2500	-19.5	-19.2	-19.8	-19.5
2700	-19.0	-17.0	-19.4	-19.4
2900	-15.1	-14.9	-15.0	-14.8

FREQUENCY (REGISTER NO. 2)

1900	1905
2100	2105
2300	2304
2500	2505
2700	2703
2900	2905

TABLE B-20

TONE GENERATOR OUTPUT AN/TTC-13 SN 1
(TEST TONE ANSWERING CIRCUIT)

Tone Generator	Frequency	Output Signal Level (dbm)
600	608	-19.5
1000	1002	- 6.2

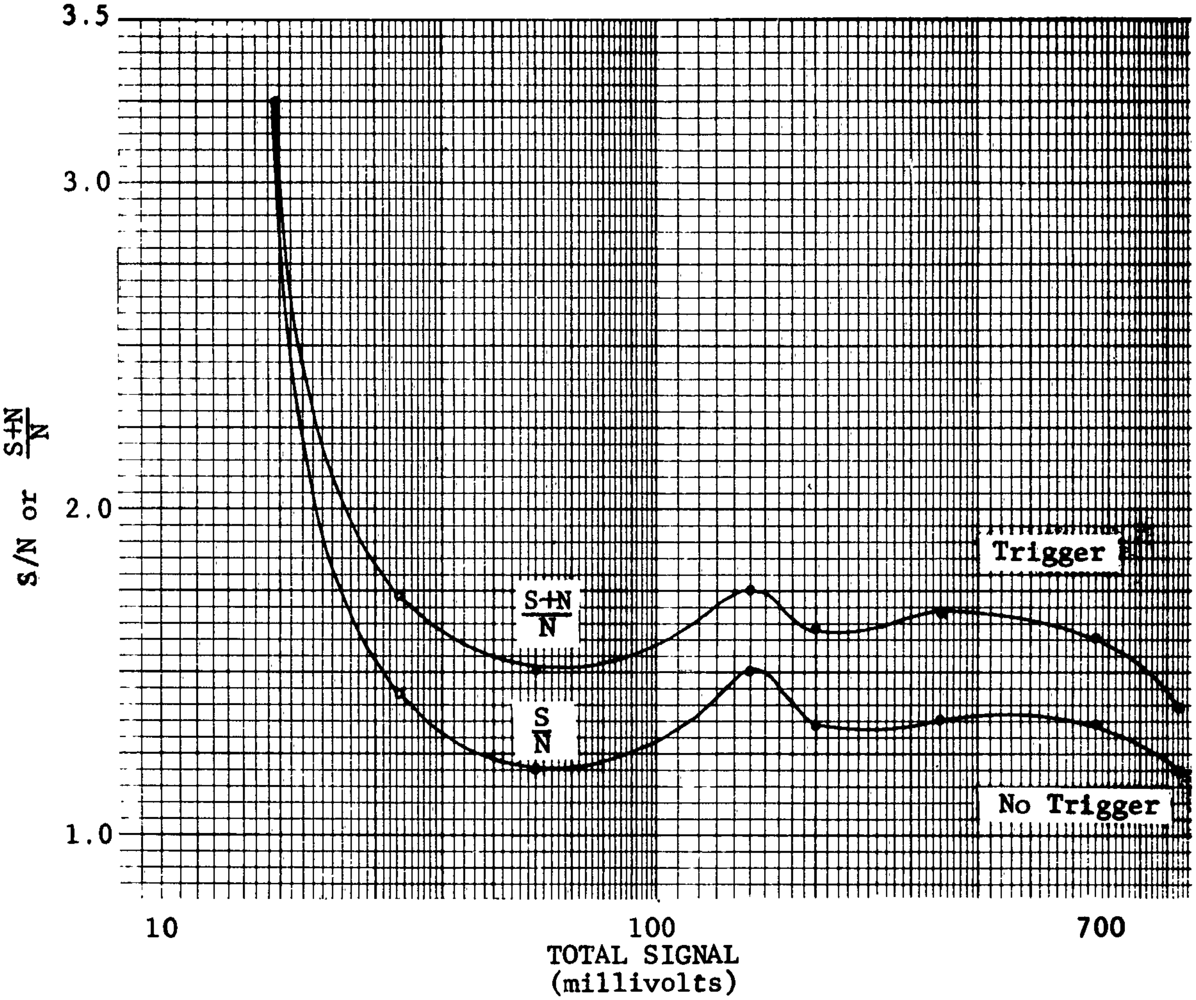


FIGURE B-58

SEIZE, SIGNAL TO NOISE (S/N) AND SIGNAL
PLUS NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-13 SN 1

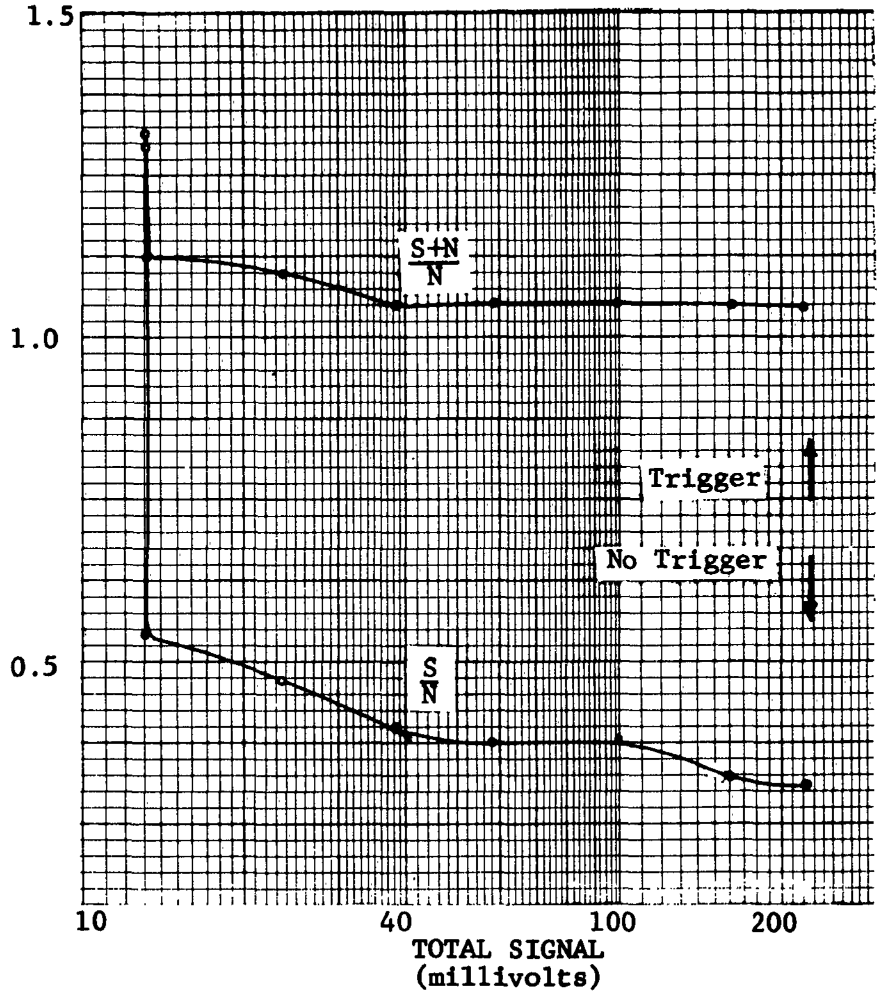


FIGURE B-59

RELEASE SIGNAL TO NOISE (S/N) AND SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-13 SN 1

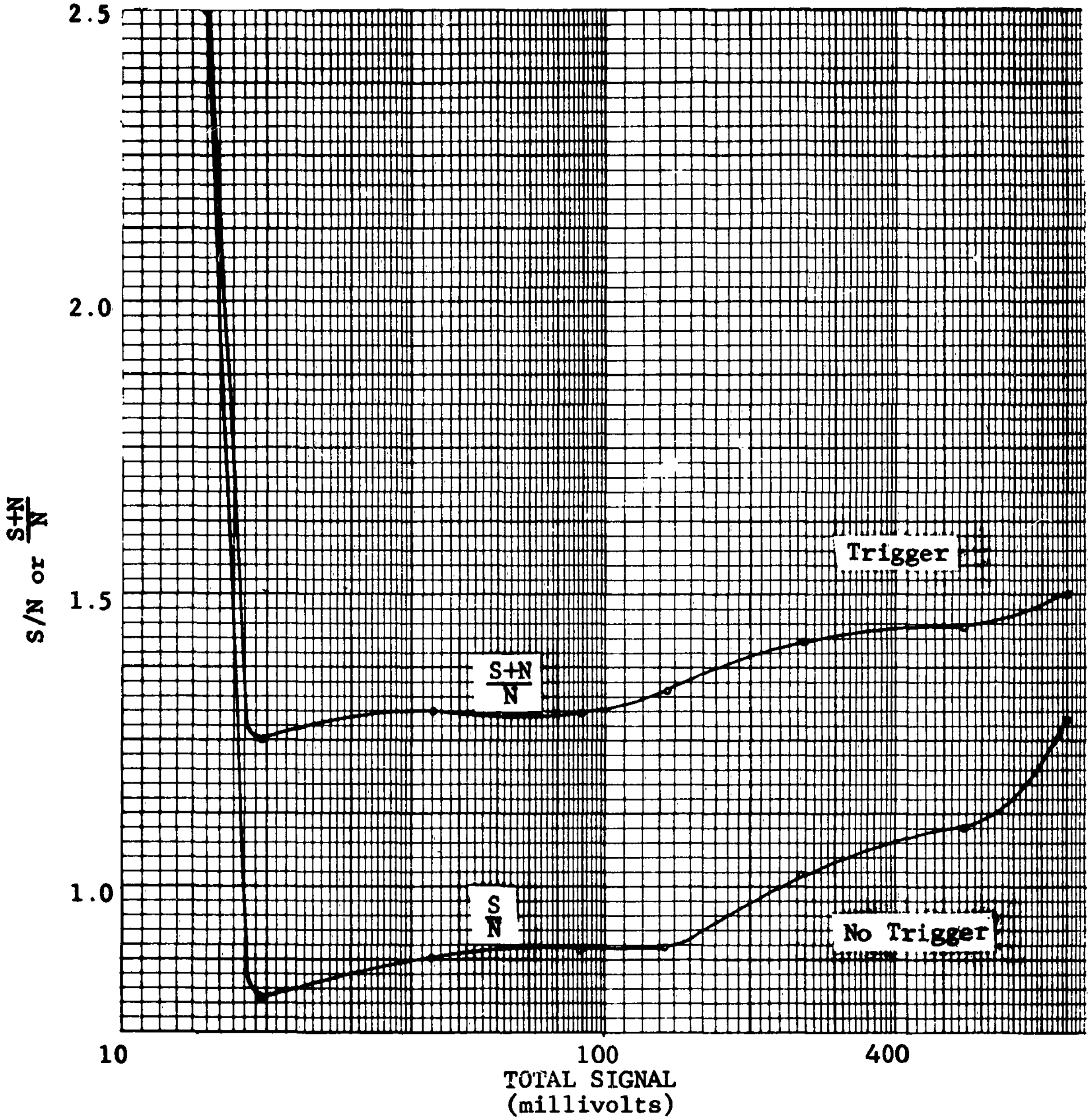


FIGURE B-60

DIGIT 3 SIGNAL TO NOISE $\frac{S}{N}$ AND SIGNAL
PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL

AN/TTC-13 SN 1

2.3 TEST OF AN/TTC-14 AUTOMATIC ELECTRONIC SWITCHING CENTRAL

2.3.1 GENERAL DESCRIPTION OF EQUIPMENT

The AN/TTC-14 is a lower echelon exchange comprised of the following basic units:

SB - "A Unit"
SB - "B Unit"
SB - "C Unit"
Power Supply
Battery Box
Storage Battery

2.3.2 OPERATIONAL DESCRIPTION

The AN/TTC-14 can be connected to other AN/TTC-14 switchboards, local exchanges, tandem switchboards, or long distance boards. It can handle from twenty to sixty lines depending on the configuration employed.

2.3.3 TECHNICAL DESCRIPTION

Electrically the AN/TTC-14 is designed to be compatible with the other automatic electronic switching equipment utilizing the following signalling and supervisory tones.

Dial Tone (DT)	480 and 600 cps mixed steady
Ring Signal and Ring Back (RS, RB)	600 cps, interrupted 1 sec on, 2 sec off. Modulated at 20 cps.
Busy Tone (BT)	600 pps, 1/4 sec on, 1/4 sec off
Seize Tone (ST)	1700 cps
Digit Tones	1900-2700 cps (two tones per digit)
Type of Switching	4 wire
Transmission Bandwidth	250 to 25 Kcps $\pm$ 1 db
Insertion Loss	1 db/1000 cps
Input Impedance	600 $\pm$ 10%
Power Required	115 or 230 volts, 50-60 cps single phase, or $\pm$ 12 V batteries

2.3.4 TEST RESULTS - AN/TTC-14

2.3.4.1 INPUT IMPEDANCE

Input impedance measurements were made on random line/trunk combinations of the AN/TTC-14

SN 003, SN 001, 011, 012 and SN 002 equipments. A plot of the most probable mean of the input impedance versus frequency and the range defining the limit of excursion of sample means with a 95 per cent confidence level on AN/TTC-14 SN 003 is shown in Figure B-61. The input impedance varied from a minimum of 589 ohms at 300 cps to a maximum of 628 ohms at 4000 cps. The phase angle of the impedance did not exceed 19.0 degrees.

The input impedance found on the AN/TTC-14 SN 001, 011, 012 and SN 002 (limited tested equipments) are tabulated in Table B-21. The data obtained agrees closely with that obtained on the SN 003.

2.3.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on random line/trunk combinations of the AN/TTC-14 SN 001, 011, 012, SN 002 and SN 003 equipments. A plot of the most probable mean of the input impedance versus frequency and the range defining the limit of excursion of sample means with a 95 per cent confidence level on AN/TTC-14 SN 003 is shown in Figure B-62. The output impedance varied from a minimum of 598 ohms at 300 cps to a maximum of 636 ohms at 4000 cps. The phase angle of the impedance did not exceed 17.0 degrees.

The output impedance found on the AN/TTC-14 SN 001, 011, 012 and SN 002 (limited tested equipments) are tabulated in Table B-22. The data obtained agrees closely with that obtained on the SN 003.

The impedance of unseized lines was measured. From 300 to 1500 cps and approaching the 1700 cps seize tone frequency, the impedance rose from 5200 to 11250 ohms. Between 1500 and 2000 cps the impedance was not measurable since the seize circuitry activated. Above 2000 cps the data became unreliable with random measurements ranging from 6900 to 13,000 ohms.

2.3.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on random line/trunk combinations of the AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002 using an input signal level of -4 dbm. A plot of the frequency response for SN 003 is shown in Figure B-63. Since the average range of the excursion of the means was only 0.078 db, the range is not shown in the figure. The response was flat ($\pm$ 0.10 db) from 300 to 30,000 cps. The insertion loss at 1000 cps was -1.3 db.

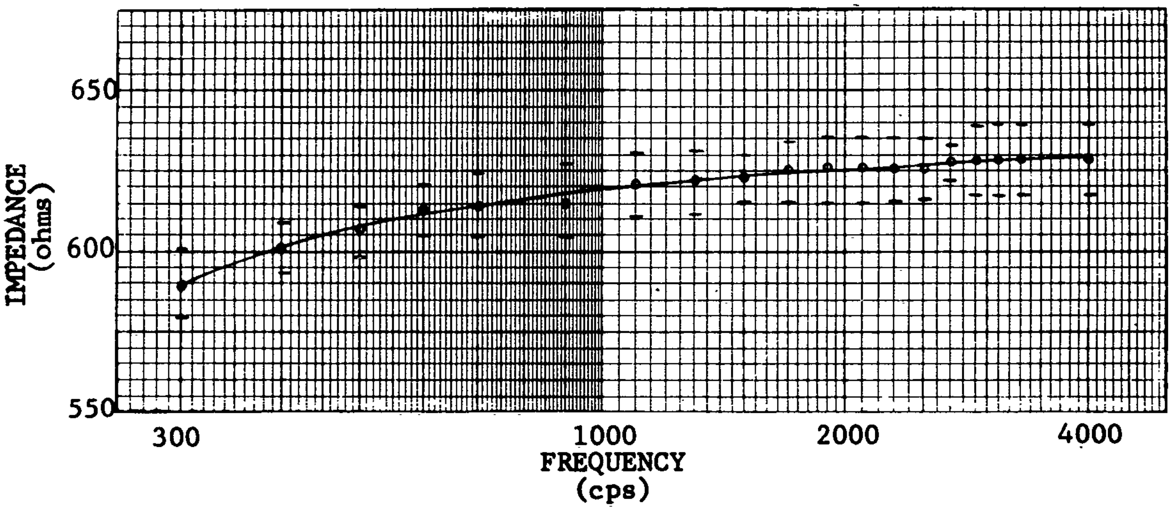


FIGURE B-61

INPUT IMPEDANCE - AN/TTC-14 SN 003
Statistically Derived

TABLE B-21

INPUT IMPEDANCE - AN/TTC-14 SN 001, 011, 012 and SN 002

FREQUENCY	IMPEDANCE (Ohms) SN 001, 011, 012	IMPEDANCE (Ohms) SN 002
300	589	576
400	601	590
500	606	597
600	609	602
700	614	604
800	---	608
900	615	610
1000	---	613
1100	619	---
1200	---	615
1300	619	---
1400	---	616
1500	619	---
1600	---	618
1700	622	---
1800	---	618
1900	622	---
2000	---	621
2100	622	---
2200	---	621
2300	623	---
2400	---	621
2500	622	---
2600	---	623
2700	622	---
2800	---	622
2900	622	---
3000	---	622
3100	622	---
3200	---	622
3300	623	---
3400	---	622
3500	623	---
3600	---	622
3800	---	622
4000	623	622

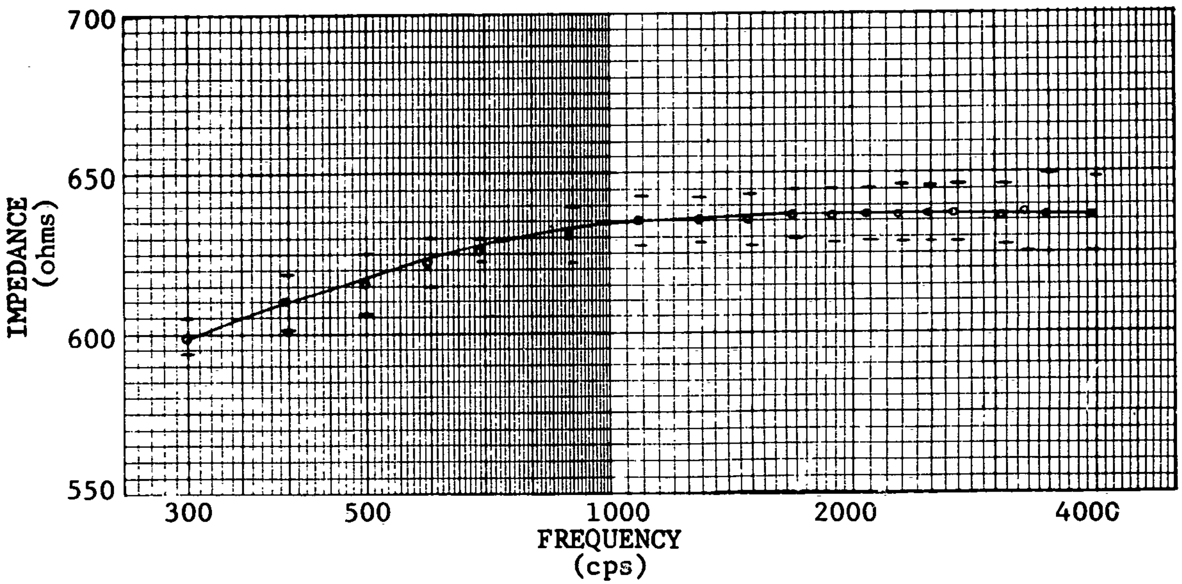


FIGURE B-62

OUTPUT IMPEDANCE - AN/TTC-14 SN 003
Statistically Derived

TABLE B-22

OUTPUT IMPEDANCE - AN/TTC-14 SN 001, 011, 012 AND SN 002

FREQUENCY	IMPEDANCE (ohms) SN 001, 011, 012	SN 002
300	602	595
400	615	610
500	625	616
600	629	623
700	633	626
800	---	628
900	636	630
1000	---	632
1100	639	---
1200	---	635
1300	641	---
1400	---	638
1500	641	---
1600	---	638
1700	642	---
1800	---	638
1900	642	---
2000	---	640
2100	642	---
2200	---	640
2300	645	---
2400	---	641
2500	646	---
2600	---	640
2700	646	---
2800	---	640
2900	646	---
3000	---	643
3100	645	---
3200	---	643
3300	646	---
3400	---	643
3500	646	---
3600	---	643
3800	---	643
4000	646	643

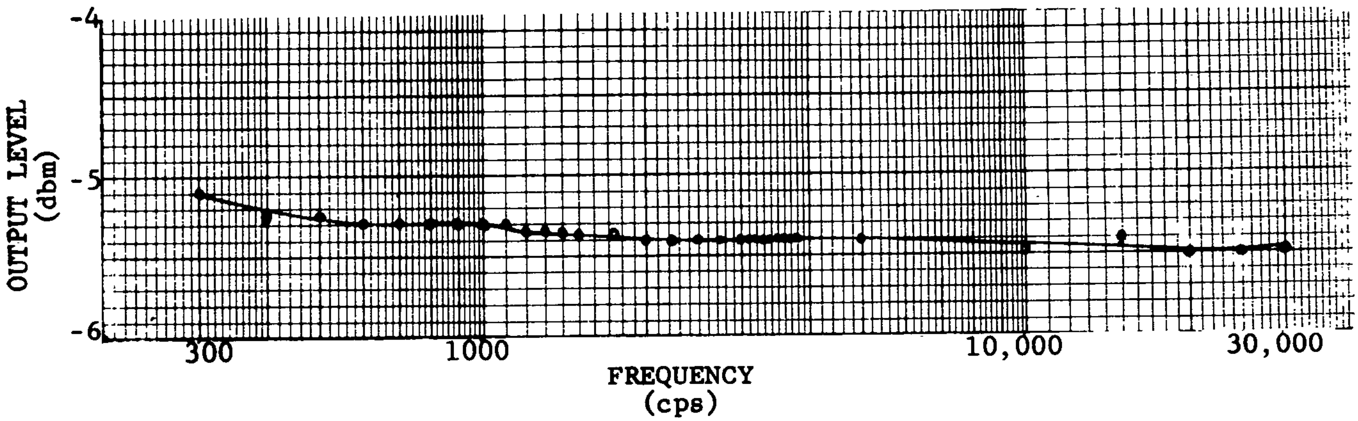


FIGURE B-63

FREQUENCY RESPONSE - AN/TTC-14 SN 003
Statistically Derived
Input Level -4 dbm

The frequency response found on AN/TTC-14 SN 001, 011, 012 and SN 002 (limited tested equipments) are tabulated in Table B-23. The data obtained agrees closely with that obtained on the SN 003

2.3.4.4 CROSSTALK LOSS

Measurements were made of near end and far end crosstalk loss on random line/trunk combinations of the AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002 equipments. An input signal level of -4 dbm was used. A plot of the most probable mean for near end and far end crosstalk loss obtained on the SN 003 for random line/trunk combinations is shown in Figure B-64. The statistical range of excursion of the means for a 95 per cent confidence level was well under 1 db. Therefore, the range was not plotted on the figure.

The crosstalk loss obtained on AN/TTC-14 SN 001, 011, 012 and SN 002 (limited tested equipments) using an input signal level of -4 dbm is tabulated in Tables B-24 and B-25.

A crosstalk loss test was made to determine the degree of crosstalk disturbance imposed on a line with increasing numbers of disturbing lines (loading). The data obtained is tabulated in Table B-26. From the data, it is evident that the amount of crosstalk is not materially effected by increased loading.

2.3.4.5 HARMONIC DISTORTION

The harmonic distortion produced in the AN/TTC-14 SN 003, SN 001, 011, 012, and SN 002 equipments was found to be within the instrumental accuracy of the testing equipment (0.2%) and therefore, considered not measurable with the instruments available.

2.3.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on random line/trunk combinations of AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002 equipments. A pair of fundamental frequencies (f_1 and f_2) separated by 200 cps and producing a total input signal level of -4 dbm were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$) cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$) and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distortion products falling within the equipment passband

TABLE B-23

FREQUENCY RESPONSE - AN/TTC-14 SN 001, 011, 012 AND SN 002
Input Level -4 dbm

FREQUENCY	OUTPUT LEVEL (dbm) SN 001, 011, 012 Lines tested 8	SN 002 Lines tested 5
100	---	- 6.4
200	---	- 5.5
300	- 5.6	- 5.3
400	- 5.6	- 5.3
500	- 5.5	- 5.2
600	- 5.4	- 5.2
700	- 5.4	- 5.2
800	- 5.4	- 5.2
900	- 5.3	- 5.1
1000	---	- 5.1
1100	- 5.3	- 5.1
1200	---	- 5.1
1300	- 5.2	- 5.1
1400	---	- 5.1
1500	- 5.1	- 5.1
1600	---	- 5.1
1700	---	- 5.1
2000	- 5.2	- 5.1
2250	---	- 5.1
2500	- 5.2	- 5.1
2750	---	- 5.1
3000	- 5.2	- 5.1
3100	---	- 5.1
3200	- 5.2	- 5.2
3300	---	- 5.2
3400	---	- 5.2
3500	- 5.2	- 5.2
3600	---	- 5.2
3700	---	- 5.2
3800	- 5.2	- 5.2
4000	---	- 5.1
5000	---	- 5.2
10000	---	- 5.0
15000	---	- 5.0

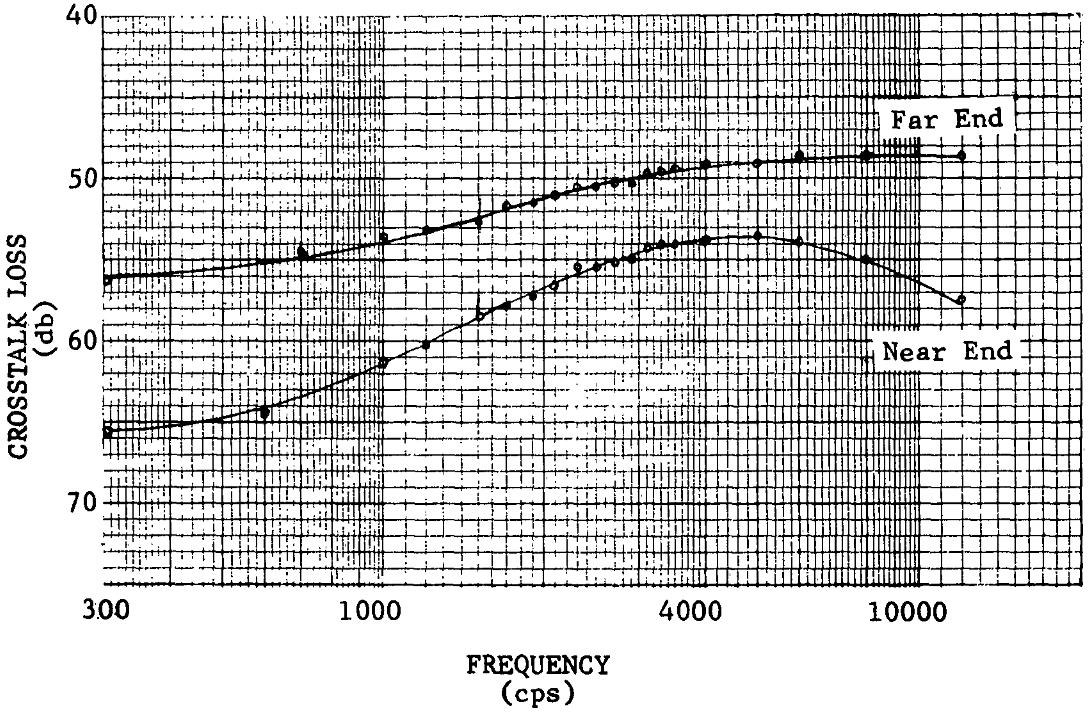


FIGURE B-64

CROSSTALK LOSS - AN/TTC-14 SN 003
Statistically Derived
Input Level -4 dbm

TABLE B-24

CROSSTALK LOSS - AN/TTC-14 SN 001, 011, 012
Lines Tested 12

FREQUENCY	CROSSTALK LOSS (dbm)	
	NEAR END	FAR END
300	78	62
600	78	61
1000	78	61
1200	77	60
1500	76	60
1700	75	60
1900	74	60
2100	74	60
2300	74	59
2500	73	59
2700	73	59
2900	73	59
3100	73	59
3300	73	59
3500	73	59

TABLE B-25

CROSSTALK LOSS - AN/TTC-14 SN 002
Lines Tested 5
Input Level -4 dbm

FREQUENCY	CROSSTALK LOSS (db) NEAR END	CROSSTALK LOSS (db) FAR END
300	76.2	74.2
600	75.0	70.6
1000	72.0	68.1
1200	70.0	66.8
1500	69.1	65.7
1700	68.1	64.7
1900	66.9	63.4
2100	66.4	62.4
2300	65.8	62.0
2500	64.9	61.3
2700	64.5	61.0
2900	64.4	60.7
3100	64.1	60.0
3300	63.8	59.6
3500	63.7	60.2

TABLE B 26

LOADING EFFECTS ON CROSSTALK LOSS - AN/TTC-14 SN 003

DISTURBING LINES	DISTURBED LINE	FREQUENCIES	CROSSTALK LOSS (db)	
			Near End	Far End
6-8,5-9,4-10,3-11	7-12	900,1000,1100,1200	59.0	58.9
6-8,5-9,4-10	7-12	900,1000,1100	59.7	59.2
6-8,5-9	7-12	900,1000	60.1	59.5
15-17,14-18,13-19,12-20	16-11	900,1200,1100,1000	55.1	56.8
15-17,14-18,13-19	16-11	900,1200,1100	55.4	56.8
15-17,14-18	16-11	900,1200	55.4	56.8
17-16,19-18,14-15,13-12	20-11	1200,900,1000,1100	57.5	57.0
17-16,19-18,14-15	20-11	1200,900,1000	60.4	58.0
17-16,19-18	20-11	1200,900	60.8	58.1
13-15,12-16,11-17,10-18	9-14	900,1000,1100,1200	59.1	58.8
13-15,12-16,11-17	9-14	900,1000,1100	59.1	58.8
13-15,12-16	9-14	900,1000	59.7	58.9

Explanation: Lines 6-8, 5-9, 4-10 and 3-11 with frequencies of 900, 1000, 1100 and 1200 cps, respectively, were used simultaneously to disturb line 7-12.

6-8 means a call is simulated between line 6 and line 8.

were measured for each frequency pair as shown in Figure B-65.

The intermodulation distortion data obtained on AN/TTC-14 SN 001, 011, 012 and SN 002 (limited tested equipments), using an input signal level of -4 dbm, is tabulated in Tables B-27 and B-28. The distortion products are seen to be more than 45 db down from the fundamental.

2.3.4.7 NOISE

Noise measurements taken on random line/trunk combinations of the AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002 equipments showed the noise levels to be below 17 dba (-68 dbm), the sensitivity of the instrumentation described in the test procedures of Annex A.

2.3.4.8 PHASE DISTORTION

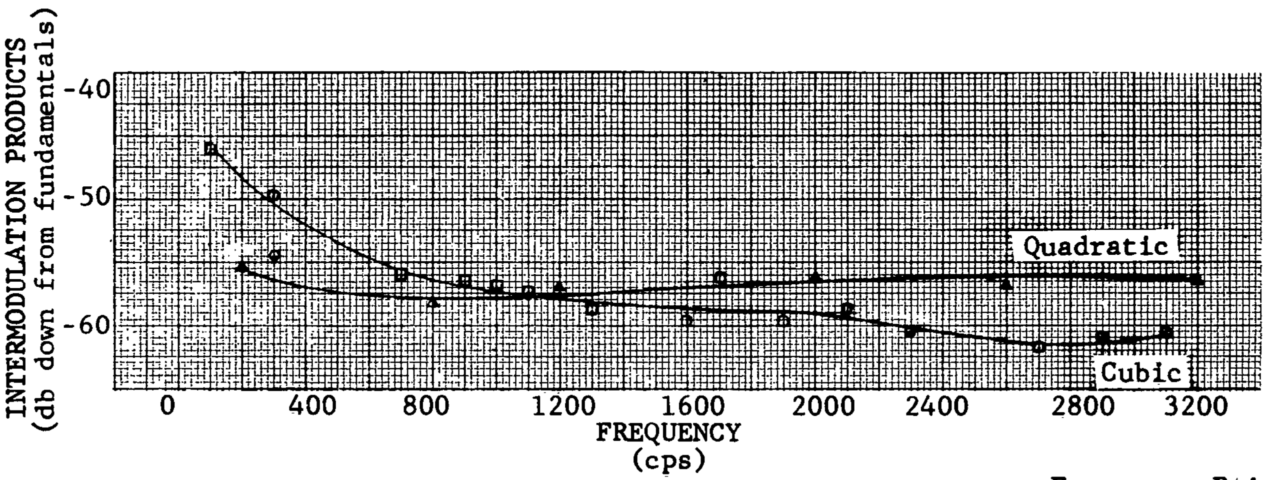
The envelope delay time in microseconds was measured on random line/trunk combinations of the AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002 using the Phazor Type 200 AB Phasemeter (accuracy 1.0 degrees). The indicated envelope delay time for these equipments was less than 16 microseconds throughout the 300 to 3500 cps range, The phase distortion coefficient was approximately 0.7. A plot of the envelope delay time in microseconds for SN 003 is shown in Figure B-66. Figure B-67 is a plot for the SN 003 of the absolute time delay in microseconds.

2.3.4.9 LONGITUDINAL BALANCE

Longitudinal balance measurements were taken between line/trunk combinations and ground on AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002. All measurements on SN 003 showed the longitudinal balance to be greater than 70 db below the referenced signal level. The measurements taken on SN 003 are tabulated in Tables B-29 through B-32.

All measurements taken on SN 001, 011, 012 showed the longitudinal balance to be greater than 67 db below the referenced signal level. The data obtained is tabulated in Tables B-33 and B-34.

All measurements taken on SN 002 showed the longitudinal balance to be greater than 69 db below the referenced signal level. The data obtained is tabulated in Table B-35.



Frequency Pairs
300-500
500-700
900-1100
1200-1400
1500-1700
1900-2100
2300-2500

FIGURE B-65

INTERMODULATION DISTORTION - AN/TTC-14 SN 003
Input Level -4 dbm (total)

TABLE B-27

INTERMODULATION DISTORTION - AN/TTC-14 SN 001, 011, 012
Lines Tested 15
Input Level -4 dbm (total)

PRIMARY FREQUENCY PAIRS	INTERMODULATION PRODUCTS (db down from fundamentals)							
	F_2-F_1	F_1+F_2	$2F_1+F_2$	$2F_1-F_2$	$2F_2+F_1$	$2F_2-F_1$	$3F_1-F_2$	$3F_2-F_1$
300 500	55.1	63.6	56.7	45.2	57.7	56.4	---	---
500 700	55.4	58.4	56.9	50.5	59.0	56.6	---	65.4
900 1100	55.5	57.3	59.5	55.4	60.3	58.3	65.0	65.5
1200 1400	55.6	57.0	---	56.9	---	59.4	65.4	65.3
1500 1700	55.5	57.2	---	57.9	---	59.4	65.6	66.0
1900 2100	55.6	---	---	58.7	---	60.2	65.9	---
2300 2500	55.3	---	---	58.9	---	61.1	---	---
2500 2700	---	---	---	---	---	---	---	---
2900 3100	---	---	---	---	---	---	---	---

TABLE B-28

INTERMODULATION DISTORTION - AN/TTC-14 SN 002
Lines Tested 5
Input Level -4 dbm (total)

PRIMARY FREQUENCY PAIRS	INTERMODULATION PRODUCTS (db down from fundamentals)					
	F_2-F_1	F_1+F_2	$2F_1+F_2$	$2F_1-F_2$	$2F_2+F_1$	$2F_2-F_1$
300 500	53.6	57.2	54.6	51.2	56.0	54.5
500 700	54.9	57.0	56.1	49.4	56.8	54.8
900 1100	56.0	56.6	57.0	54.1	57.4	55.9
1200 1400	54.4	56.5	---	56.3	---	56.6
1500 1700	54.1	56.5	---	55.8	---	56.7
1900 2100	53.9	---	---	56.5	---	57.4
2300 2500	53.9	---	---	56.7	---	57.4
2500 2700	53.7	---	---	56.9	---	57.9
2900 3100	52.2	---	---	57.2	---	58.0

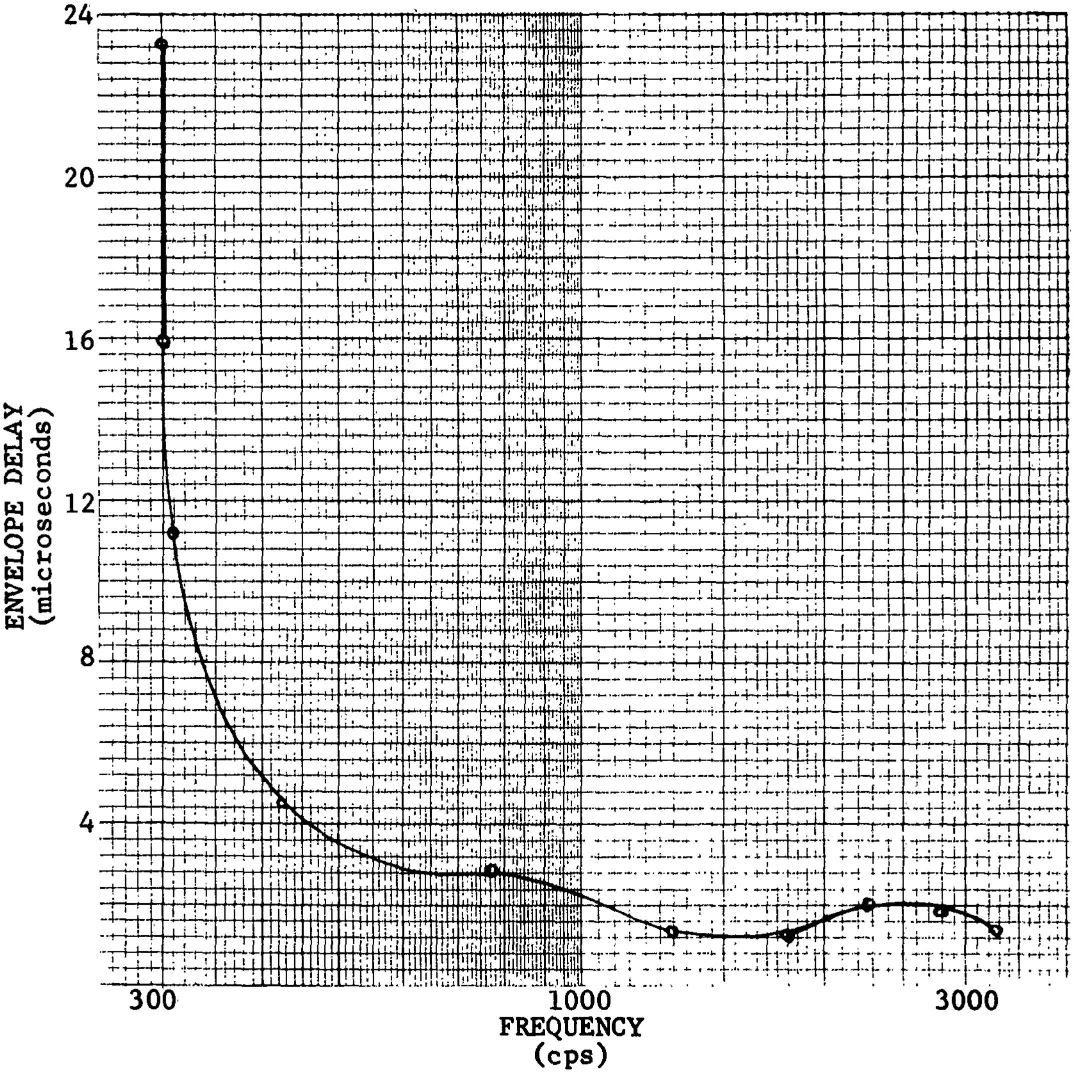


FIGURE B-66

ENVELOPE DELAY - AN/TTC-14 SN 003
Lines Tested 10
Input Level -4 dbm (total)

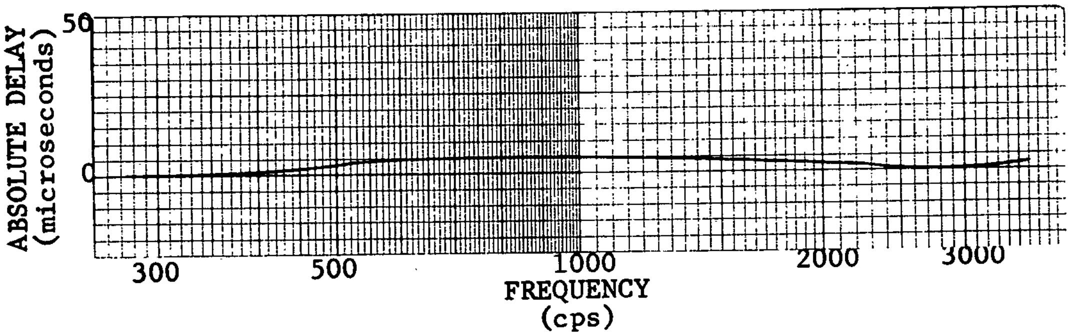


FIGURE B-67

ABSOLUTE TIME DELAY - AN/TTC-14 SN 003
Lines Tested 10
Input Level -4 dbm

TABLE B-29

LONGITUDINAL BALANCE - AN/TTC-14 SN 003
Lines Tested 20

SEND LINE	RECEIVE LINE	LINK	LONGITUDINAL BALANCE IN DECIBELS
1	2	1	72.0
2	3	2	71.8
3	4	3	70.5
4	5	4	70.2
5	6	5	73.8
6	7	1	70.4
7	8	2	70.7
8	9	3	71.6
9	10	4	71.6
10	11	5	73.3
11	12	1	74.4
12	13	2	72.2
13	14	3	70.2
14	15	4	72.3
15	16	5	70.6
16	17	1	71.6
17	19	2	70.5
18	19	3	70.4
19	20	4	70.2
20	1	5	72.8
		AVERAGE	71.6

TABLE B-30

LONGITUDINAL BALANCE - AN/TTC-14 SN 003
Trunks Tested 8

SEND TRUNK	RECEIVE TRUNK	TRUNK LINK	LONGITUDINAL BALANCE IN DECIBELS
1	2	1	74.0
2	3	2	73.1
3	4	3	71.5
4	5	4	71.2
5	6	1	71.9
6	7	2	73.1
7	8	3	72.0
8	1	4	71.1
		AVERAGE	72.2

TABLE B-31

LONGITUDINAL BALANCE - AN/TTC-14 SN 003
Lines Tested 9

LINE	TRUNK	LINE LINK	LONGITUDINAL BALANCE IN DECIBELS
1	1	1	71.8
2	2	2	71.0
3	3	3	71.6
4	4	4	71.7
5	5	5	72.8
6	6	1	71.8
7	7	2	72.5
8	8	3	71.6
9	1	4	71.9
		AVERAGE	71.9

TABLE B-32

LONGITUDINAL BALANCE - AN/TTC-14 SN 003
Trunks Tested 8

TRUNK	LINE	TRUNK LINK	LONGITUDINAL BALANCE IN DECIBELS
1	1	1	72.8
2	2	2	72.7
3	3	3	70.6
4	4	4	71.7
5	5	1	71.8
6	6	2	71.7
7	7	3	72.5
8	8	4	71.6
		AVERAGE	71.9

TABLE B-33

LONGITUDINAL BALANCE - AN/TTC-14 SN 001, 011, 012
Lines Tested 10

SEND LINE	RECEIVE LINE	LINK	LONGITUDINAL BALANCE IN DECIBELS
4	25	3	67.6
24	57	5	68.6
14	39	10	68.7
13	40	15	67.7
29	32	9	67.7
20	5	12	68.3
26	4	14	68.6
46	25	4	69.5
12	26	8	68.6
57	44	6	70.5
		AVERAGE	68.6

TABLE B-34

LONGITUDINAL BALANCE - AN/TTC-14 SN 001, 011, 012
Trunks Tested 8

SEND LINE	RECEIVE LINE	LINK	LONGITUDINAL BALANCE IN DECIBELS
14	2	1	68.7
9	11	2	71.1
12	5	3	68.2
6	13	4	69.9
5	6	5	68.3
10	4	6	70.2
8	11	7	68.2
16	15	8	70.0
		AVERAGE	69.3

TABLE B-35

LONGITUDINAL BALANCE - AN/TTC-14 SN 002
Lines Tested 10

SEND LINE	RECEIVE LINE	LINK	LONGITUDINAL BALANCE IN DECIBELS
11	19	1	69.2
5	13	2	70.6
6	4	3	71.0
15	17	4	70.0
7	9	5	70.4
12	14	1	69.6
19	16	2	69.8
18	20	3	69.9
3	1	4	69.3
2	8	5	70.0
		AVERAGE	70.0

2.3.4.10 LIMITING

Limiting was measured on random line/trunk combinations of AN/TTC-14 SN 003 SN 001, 011, 012 and SN 002. Figure B-68 is a plot of the most probable mean of limiting on SN 003 over the range of input signal levels from -12 to +12 dbm. The statistical range of excursion of the means was well under 0.2 db, hence was not plotted on the figure.

The results of limiting tests on SN 001, 011, 012 and SN 002 are tabulated in Tables B-36 and B-37.

2.3.4.11 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits of AN/TTC-14 SN 003, SN 001,011,012 and SN 002.

The open (unseized) impedance of the AN/TTC-14 is a bridging circuit offering a high impedance load to the generator. The sensitivity measurements, therefore, were taken in millivolts. Figure B-69 is a plot of the selectivity of the tone detectors in SN 003. The selectivity and sensitivity data obtained on SN 001, 011, 012 and SN 002 are tabulated in Tables B-38 and B-39. The sensitivity in millivolts for all AN/TTC-14 tone detectors tested ranged between 6.0 and 11.0 millivolts.

2.3.4.12 MFSD SIGNAL SIMULATION

Tape recordings of background noises (battle sounds, vehicle noises, horns), balanced word lists and live voice were fed into the AN/TTC-14 SN 003 electronic switching central for 1 hour and 15 minutes. The outputs of the tone detectors, the inputs to the register storage elements and the inputs to the supervisory circuits, i.e., release and recall, were monitored by recording on chart recorders.

The tone detectors were activated by various types of sounds, particularly those containing the higher audio frequencies. The register storage elements were seldom activated, since two tones must be simultaneously detected for activation. A tabulation of the number of tone detector activations made by the various sounds is given in Table B-40. The human voice produced the greatest number of simulations. Table B-41 tabulates the voice caused simulation experienced.

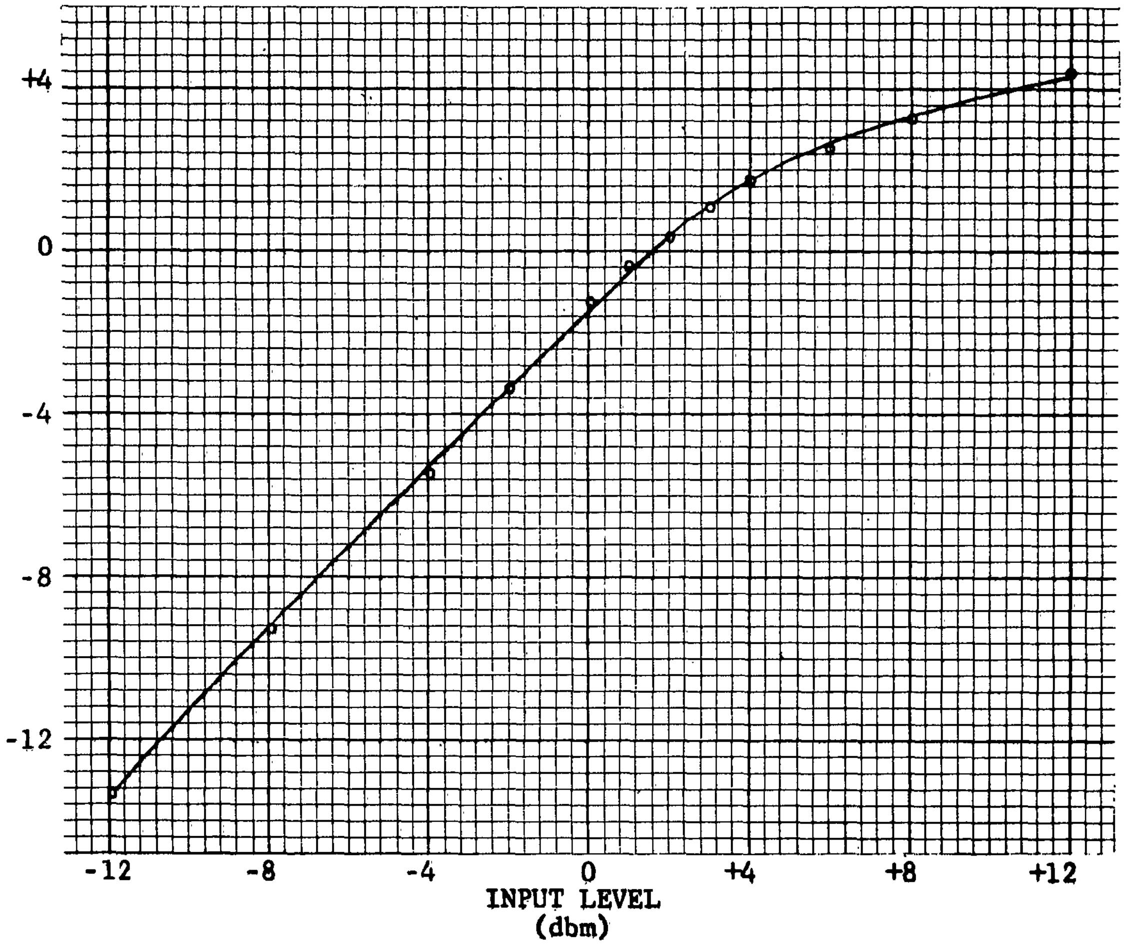


FIGURE B-68

LIMITING - AN/TTC-14 SN 003
Statistically Derived

TABLE B-36

LIMITING AN/TTC-14 SN 001, 011, 012
Lines Tested 5

INPUT LEVEL (dbm)	OUTPUT LEVEL (dbm)
-12	-14.4
- 8	- 9.4
- 4	- 5.6
- 2	- 3.4
0	- 1.3
+ 1	- 0.3
+ 2	0
+ 3	+ 0.7
+ 4	+ 1.3
+ 6	+ 2.2

TABLE B-37

LIMITING - AN/TTC-14 SN 002
Lines Tested 5

INPUT LEVEL (dbm)	OUTPUT LEVEL (dbm)
-12	-13.4
- 8	- 9.6
- 4	- 5.2
- 2	- 3.3
0	- 1.4
+ 1	- 0.3
+ 2	+ 0.2
+ 3	+ 1.3
+ 4	+ 2.2
+ 6	+ 3.5

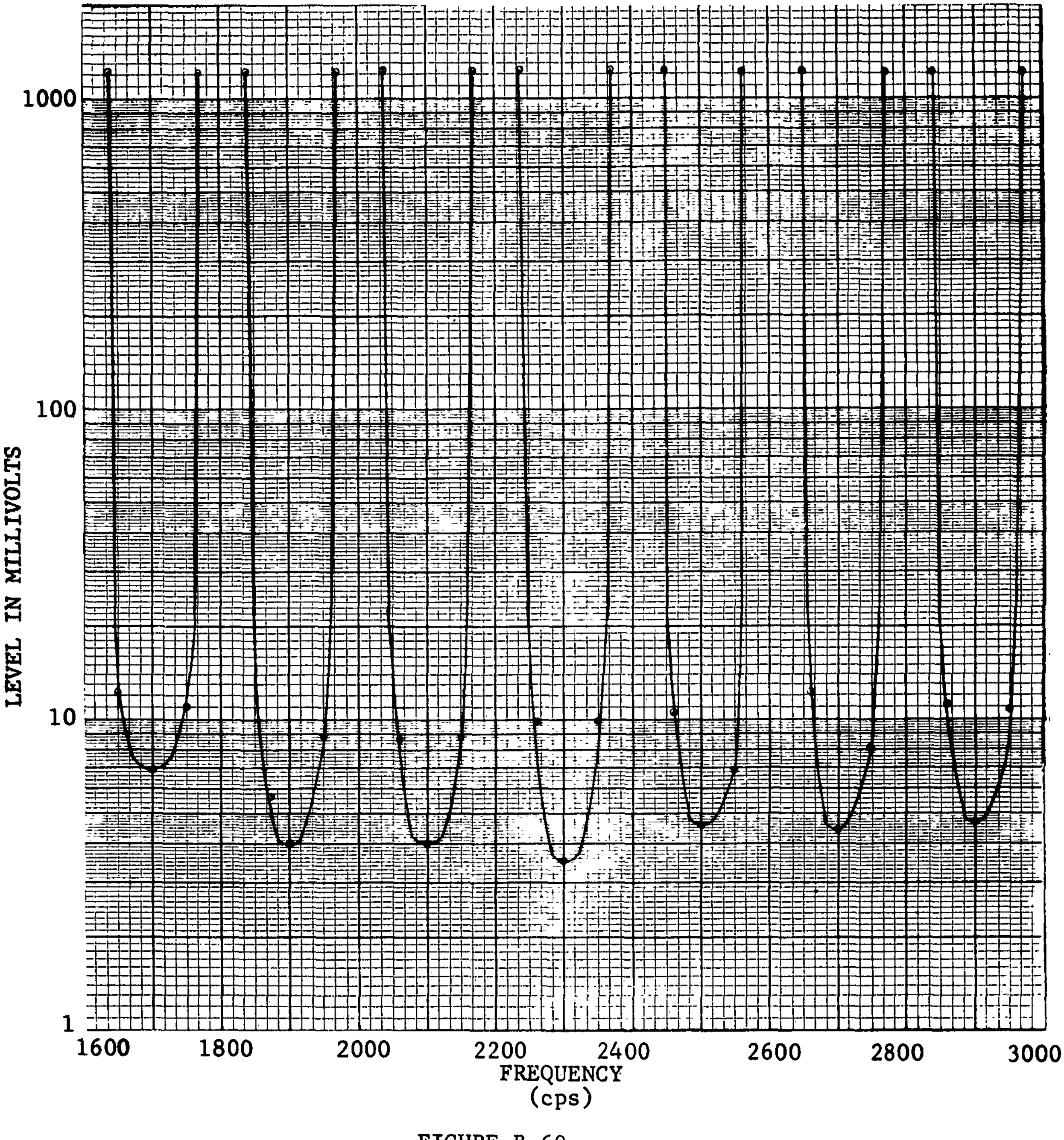


FIGURE B-69

TONE DETECTOR SELECTIVITY CURVES - AN/TTC-14 SN 003
Links 5

TABLE B-38

TONE DETECTOR SENSITIVITY AND SELECTIVITY
AN/TTC-14 SN 001, 011, 012
Lines Tested 6

TONE DETECTOR	CENTER FREQUENCY	SENSITIVITY (millivolts)	SELECTIVITY (cps)
S	1701	6.0	112
U	1902	6.8	107
V	2101	7.1	103
W	2302	6.2	103
X	2502	7.6	105
Y	2702	10.4	103
Z	2902	10.2	100

TABLE B-39

TONE DETECTOR SENSITIVITY AND SELECTIVITY
AN/TTC-14 SN 002
Lines Tested 5

TONE DETECTOR	CENTER FREQUENCY	SENSITIVITY (millivolts)	SELECTIVITY (cps)
S	1700	11.0	117
U	1900	7.0	116
V	2100	7.5	79
W	2300	6.2	117
X	2500	7.4	105
Y	2700	9.0	78
Z	2900	8.6	107

TABLE B-40

TONE DETECTORS ACTIVATED BY VARIOUS SOUNDS - AN/TTC-14 SN 003

Tones	Voice Random Word List	Battle Sounds	Jamming (C.W. & Bagpipe)	Back-ground	Tele-type	Tele-phone	"Yankee Go Home" (Re-peated 22 times)	Train Whis-	Train Bell	Total ("Yankee Go Home" Not In-cluded)
1700(S)	135	1	5	3	0	16	5	10	0	170
1900(U)	126	0	7	2	0	0	26	2	0	137
2100(V)	58	0	0	0	0	0	14	0	0	58
2300(W)	117	0	0	1	0	0	23	0	0	118
2500(X)	88	0	11	0	10	0	0	0	13	122
2700(Y)	1	0	0	0	2	0	2	0	0	3
2900(Z)	30	0	0	0	0	0	5	0	0	30

TABLE B-41

DIGITS SIMULATED BY THE HUMAN VOICE - AN/TTC-14 SN 003

DIGITS	VOICE	SNORE	"YANKEE GO HOME" "Repeated 22 Times)	TOTAL ("Yankee Go Home Not Included)
YZ (Release)	2	0	0	2
WZ (Recall)	0	0	0	0
UX (Zero)	1	1	0	2
VW (One)	2	0	8	2
XW (Two)	7	0	0	7
UV (Four)	5	1	8	6
XY (Five)	2	0	0	2
YW (Six)	0	0	0	0
VX (Seven)	1	0	0	1
UW (Eight)	0	0	7	0
VY (Nine)	0	0	0	0

It was also determined that erroneous releases can be experienced when two handsets are operating in close physical proximity. The release tone signal generated by hanging up one handset can be audibly picked up by the transmitter of the second handset and can cause undesired release of this circuit.

2.3.4.13 TONE GENERATOR OUTPUT

The frequency and power output of the several tone generators of AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002 were measured. The data obtained, measured at the output terminals of the central, are tabulated in Tables B-42, B-43 and B-44.

2.3.4.14 SIGNAL TO NOISE AND SIGNAL TO SIGNAL

Signal to noise and signal plus noise to noise ratios were determined on the AN/TTC-14 SN 003, SN 001, 011, 012 and SN 002.

For accuracy at the low signal levels used in this test, S/N and $\frac{S+N}{N}$ ratios were determined using millivolt measurements. Also, due to the variation of input impedance of the board, occurring at different stages of the keying sequence, db measurements would have been less accurate. Plots showing the effect of noise upon the sensitivity of detector circuitry of SN 001, 011, 012 and SN 002 are shown in Figures B-70 through B-73.

Signal to signal versus total signal ratios measured on the SN 003 are shown in Figure B-74.

2.4 TEST OF AN/TTC-15 AUTOMATIC ELECTRONIC SWITCHING CENTRAL

2.4.1 GENERAL DESCRIPTION

The AN/TTC-15 is a transportable, transistorized, completely automatic, division tandem telephone switching central The central utilizes a time-division multiplexing principle with pulse-amplitude modulation on a four wire basis. It is permanently housed in a S-141 shelter and can be mounted on a 2-1/2 ton cargo truck. The equipment operates from 120 volt commercial lines or a 10 KW, 120 volt engine driven power unit.

TABLE B-42

TONE GENERATOR OUTPUT - AN/TTC-14 SN 003

TONE GENERATOR	FREQUENCY (cps)	OUTPUT LEVEL (dbm)
Dial	481	-17.9
Dial	601	-17.8
Ringback	601	-18.2
Ring	601	- 0.5
Line Busy	601	-18.1
Trunk Busy	601	-18.0
Tones	1700	-18.3
Tone U	1903	-23.7
Tone V	2100	-23.6
Tone W	2302	-23.7
Tone X	2501	-24.4
Tone Y	2700	-23.4
Tone Z	2901	-21.0
Release	2700	-22.2
Release	2901	-22.2

TABLE B-43

TONE GENERATOR OUTPUT - AN/TTC-14 SN 001, 011, 012

TONE GENERATOR	FREQUENCY (cps)	OUTPUT LEVEL (dbm)
Dial-Line	600	-18.2
Dial-Trunk	480	-18.2
Ringback	601	-18.0
Ring	601	0.0
Line Busy	601	-18.4
Trunk Busy	601	-18.4
Tone S	1700	-18.3
Tone U	1902	-24.3
Tone V	2101	-24.1
Tone W	2302	-24.2
Tone X	2502	-24.2
Tone Y	2702	-24.2
Tone Z	2902	-18.4
Release	2700	-17.2
Release	2900	-18.4

TABLE B-44

TONE GENERATOR OUTPUT - AN/TTC-14 SN 002

TONE GENERATOR	FREQUENCY (cps)	OUTPUT LEVEL (dbm)
Dial Line	600	-18.2
Dial Trunk	480	-18.2
Ringback	600	-18.1
Ring	600	- 0.5
Line Busy	600	-18.5
Trunk Busy	600	-18.7
Tone S	1700	-18.2
Tone U	1901	-24.3
Tone V	2100	-24.3
Tone W	2299	-24.5
Tone X	2502	-24.2
Tone Y	2700	-24.3
Tone Z	2900	-24.7
Release	2700	-19.0
Release	2900	-19.5

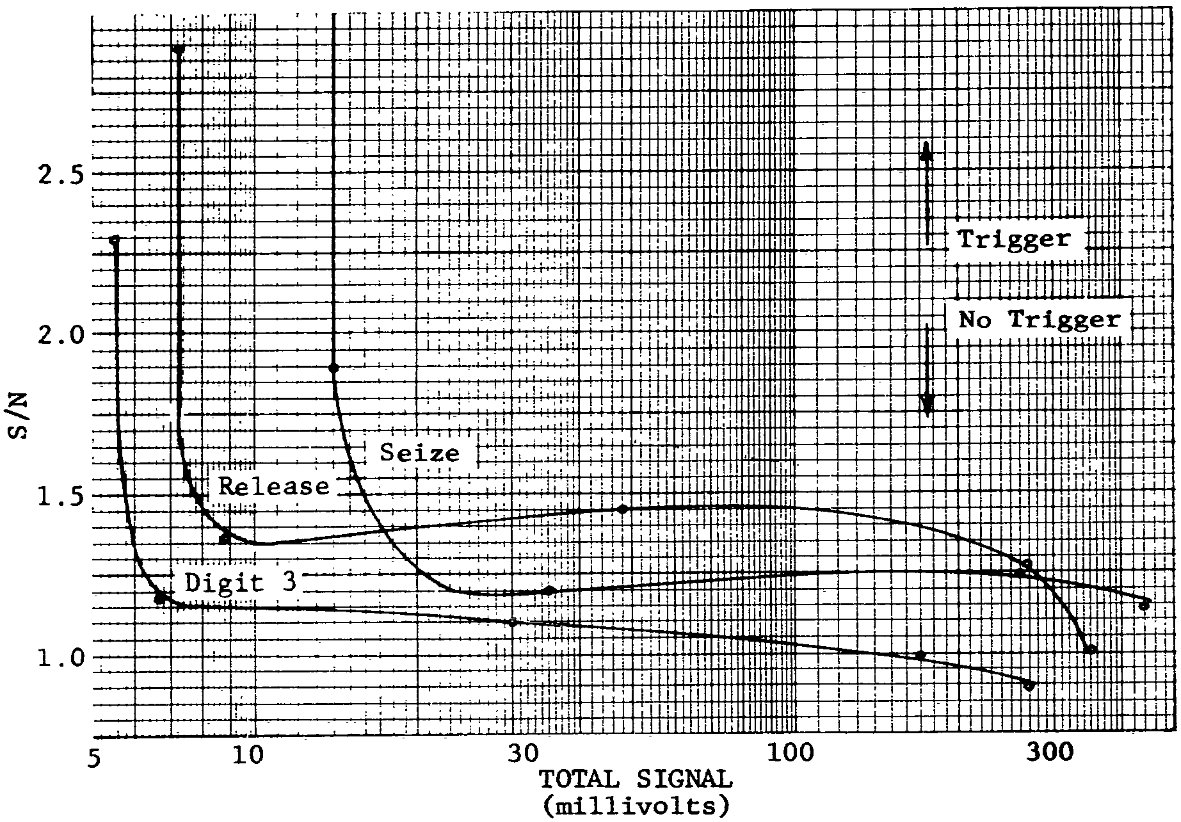


FIGURE B-70

DIGIT 3, RELEASE AND SEIZE SIGNAL TO NOISE $\frac{S}{N}$
VERSUS TOTAL SIGNAL - AN/TTC-14 SN 001, 011, 012

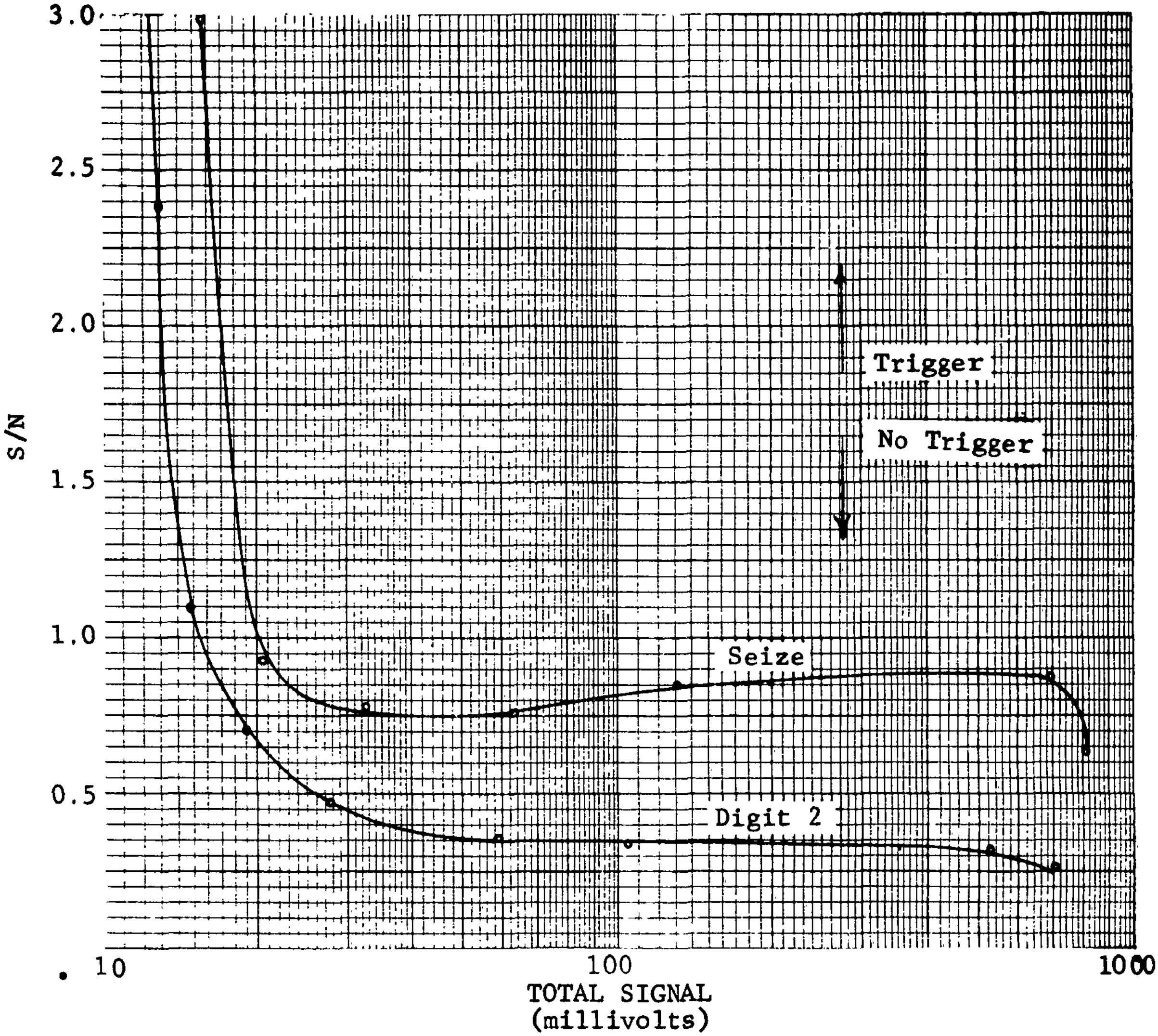


FIGURE B-71

DIGIT 2 AND SEIZE SIGNAL TO NOISE $\frac{S}{N}$
VERSUS TOTAL SIGNAL - AN/TTC-14 SN 002

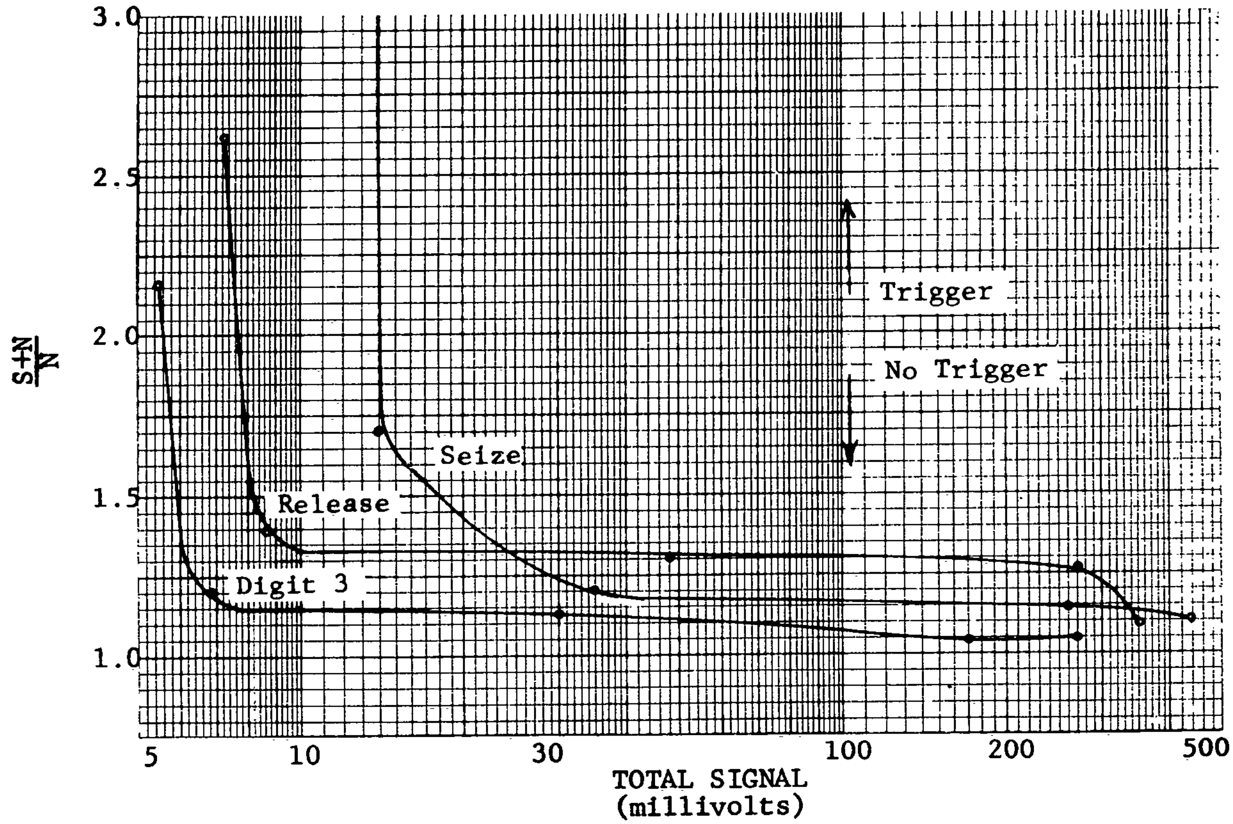


FIGURE B-72

DIGIT 3, RELEASE AND SEIZE SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$
VERSUS TOTAL SIGNAL - AN/TTC-14 SN 002

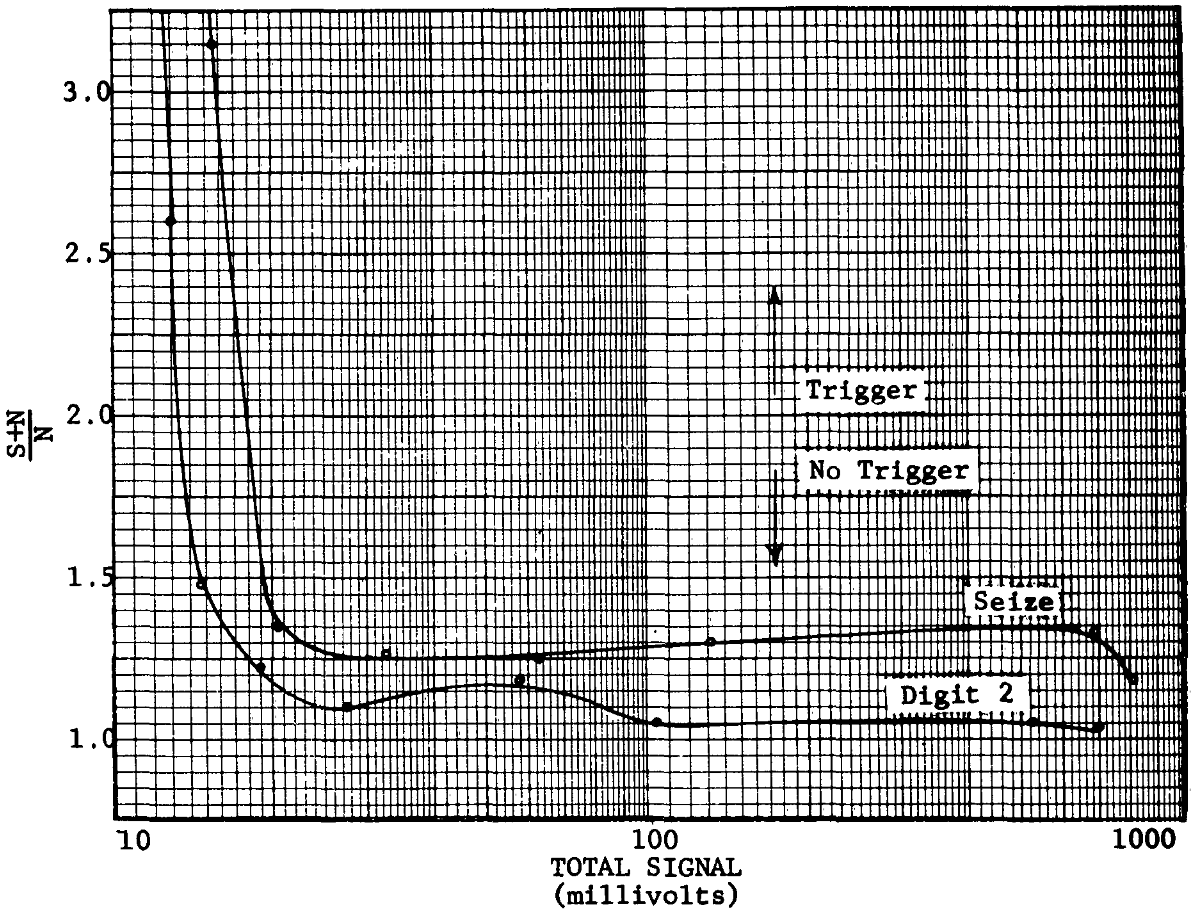


FIGURE B-73

DIGIT 2 AND SEIZE SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$
VERSUS TOTAL SIGNAL - AN/TTC-14 SN 002

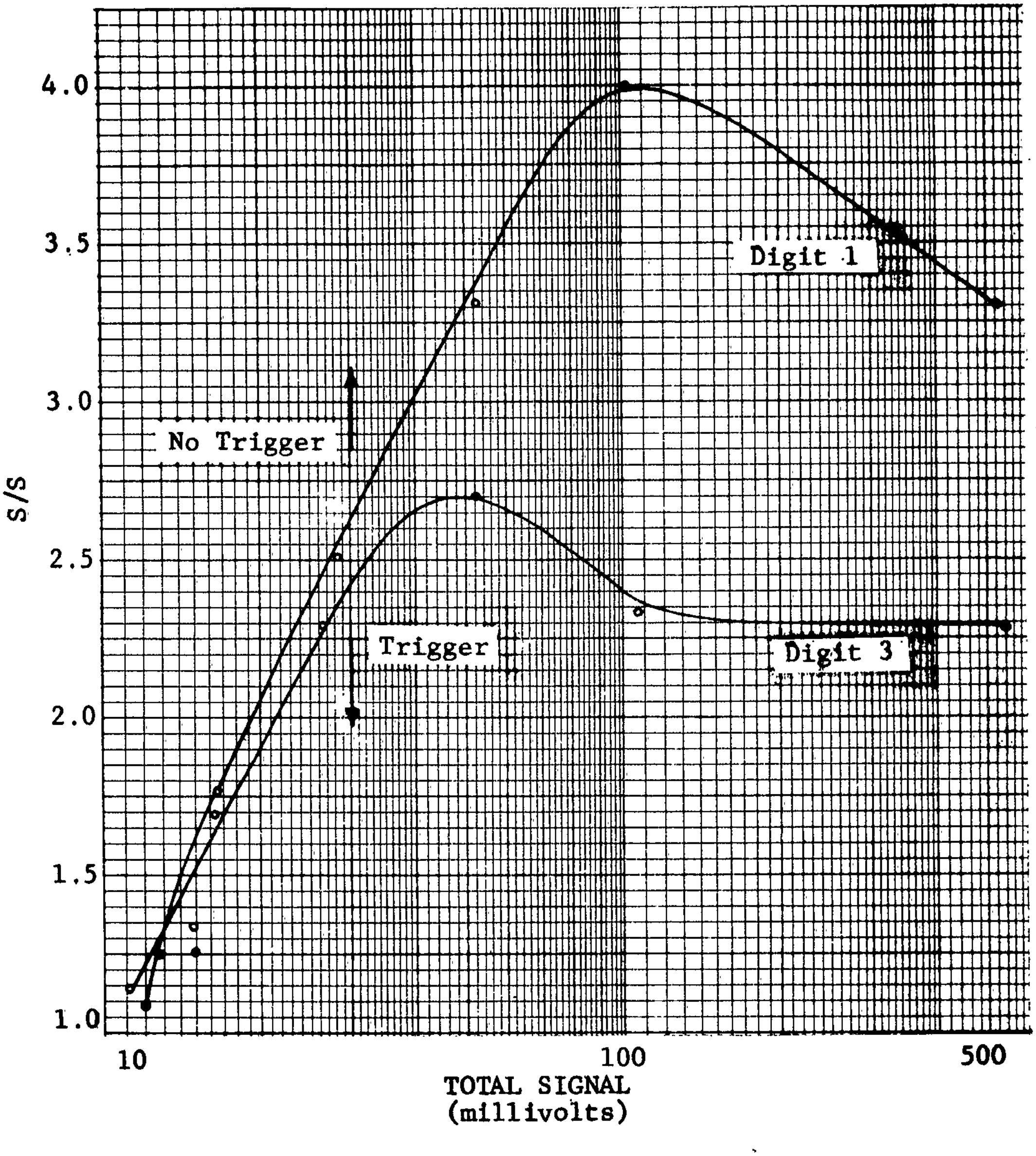


FIGURE B-74

DIGITS 1 AND 3 SIGNAL TO SIGNAL $\frac{S}{S}$
VERSUS TOTAL SIGNAL AN/TTC-14 SN 003

2.4.2 OPERATIONAL DESCRIPTION

The AN/TTC-15 operates in a tandem system with two or more similar centrals, each of which is capable of handling seventy simultaneous calls and providing access for the following: (a) one group of eighteen long distance trunks which are connected to a long distance switching central (AN/TTC-13); (b) seventy-two trunks, which may be divided into twenty groups, connected to local centrals (AN/TTC-12). The number of trunks in any one group may not exceed eighteen; (c) three groups of tie trunks to other division area centrals; (d) two service lines (operator position and wire chief).

A call placed through a tandem central to a local central not directly connected to this same tandem will be automatically routed over a tie trunk to another tandem which does have direct connection to the called local central. Calls to a long distance central are automatically routed in the same manner.

When a number is used at one tandem central to designate a trunk group to a specific local central, that number is reserved at all other tandem centrals within the tandem network. By this means a local switching central may be moved from one tandem central to another yet retaining the same identity.

Other than the diverse tandem operation of the AN/TTC-15, all switching operations performed are similar to the switching operations of the local central, AN/TTC-12.

2.4.3 TECHNICAL DESCRIPTION

(1)	Total lines and trunks	140
(2)	Long distance trunks	18
(3)	Tie trunks to other AN/TTC-15 centrals	48
(4)	Trunks to local switch-boards	72
(5)	Service lines	2
(6)	Signalling - all signalling is done by single or compound tones.	
(7)	Signalling Code Assignment	

S - 1700 cps	X - 2500 cps
U - 1900 cps	Y - 2700 cps
V - 2100 cps	Z - 2900 cps
W - 2300 cps	

Digital Signals

1 - VW	6 - YU
2 - XW	7 - VX
3 - UY	8 - UW
4 - UV	9 - VY
5 - XY	0 - UX

Dial tone - 600 cps
Ring Signal - 600/20 cps (1 sec on, 2 sec off)
Busy Tone (line) - 600 cps (1/2 sec on, 1/2 sec off)
Ring Back Tone - 600 cps (1 sec on, 2 sec off)
Signal duration for detection - 50 msec

(8) Channel Transmission Characteristics

Transmission - time division multiplexing

One frame period (32 time slots)	80 μ sec
One time slot	2.5 μ sec
Sampling time	1.25 μ sec
Guard time	1.25 μ sec
Frame repetition frequency	12.5 KC

2.4.4 TEST RESULTS AN/TTC-15

2.4.4.1 INPUT IMPEDANCE

Input impedance measurements were made on random trunk to trunk combinations of the AN/TTC-15 SN 3. A plot of the most probable mean of the input impedance versus frequency and the range defining the limits of excursion of sample means with a 95 per cent confidence level is shown in Figure B-75. The input impedance varied from a minimum of 556 ohms at 300 cps to a maximum of 674 ohms at 2400 cps. The phase angle did not exceed 20.0 degrees.

2.4.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on random trunk to trunk combinations of the AN/TTC-15 SN 3. A plot of the most probable mean of the output impedance versus frequency and the range defining the limits of excursion of sample means with a 95 per cent confidence level is shown in Figure B-76. The output impedance varied from 576 ohms at 310 cps to a maximum of 666 ohms at 3800 cps. The phase angle of the impedance did not exceed 26.8 degrees.

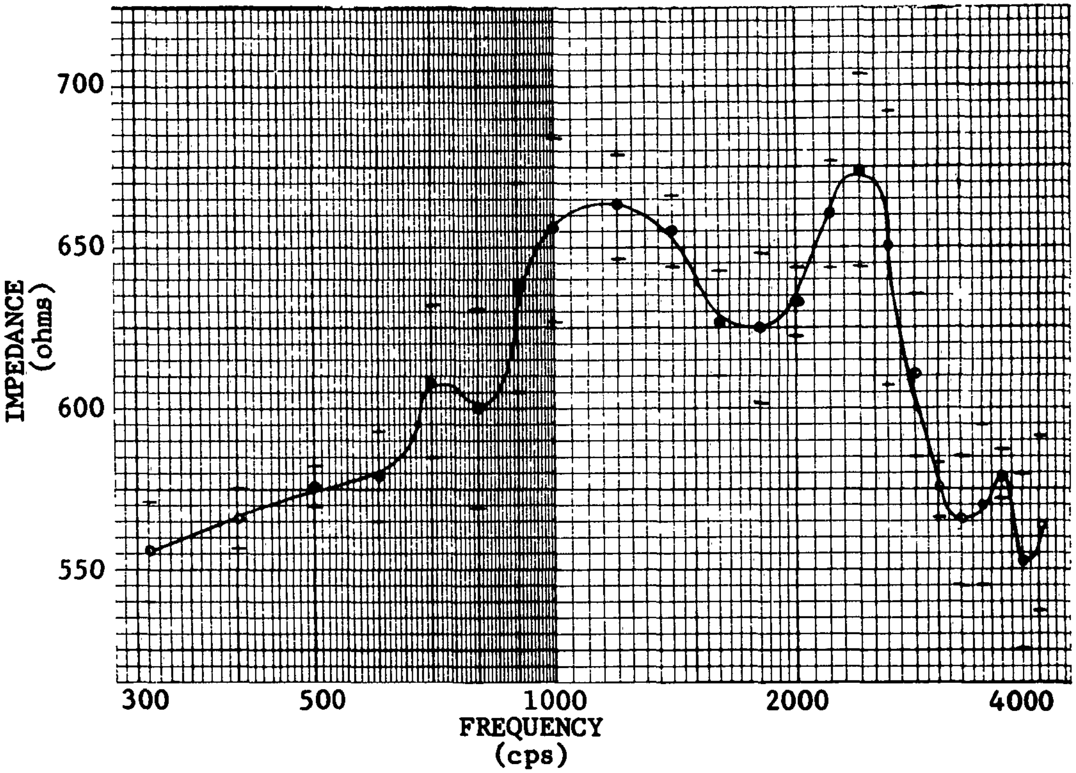


FIGURE B-75

INPUT IMPEDANCE - AN/TTC-15 SN 3
Statistically Derived

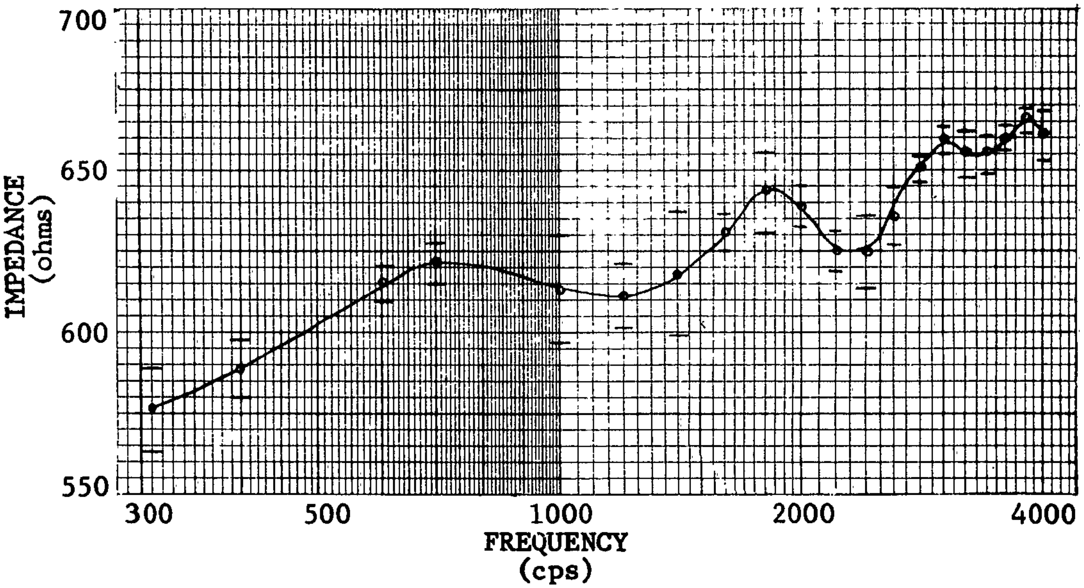


FIGURE B-76

OUTPUT IMPEDANCE - AN/TTC-15 SN 3
Statistically Derived

2.4.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on random trunk to trunk combinations of the AN/TTC-15 SN 3 using an input signal level of -4 dbm. The response was flat ($\pm$ 0.5 db) from 300 to 3500 cps. The insertion loss at 1000 cps was -0.8 dbm. A plot of the most probable means of frequency response is shown in Figure B-77. The range of excursion of the means was below 0.1 db, hence was not plotted on the curve.

2.4.4.4 CROSSTALK LOSS

Measurements were made of the near end and far end crosstalk loss on random trunk to trunk combinations of the AN/TTC-15 SN 3 using two internal routings through the switching centrals; namely, same time slot - adjacent highway and adjacent time slot - same highway. Figure B-78 shows the most probable means of the crosstalk loss for the same time slot adjacent highway routing. As shown, the crosstalk loss is more than 55 db down from the input signal (disturbing signal) level of -4 dbm for all trunk combinations tested. No detectable crosstalk was observed with the same highway - adjacent time slot routing.

2.4.4.5 HARMONIC DISTORTION

Harmonic distortion measurements were made on random trunk to trunk combinations of the AN/TTC-15 SN 3. A plot of the most probable mean of the harmonic distortion versus frequency with an input level of -4 dbm is shown in Figure B-79. The range of excursion of the means with a 95 per cent confidence level was below 0.2 per cent, the accuracy of the instrumentation, hence was not plotted on the curve.

2.4.4.6 INTERMODULATION DISTORTION

Due to the failure of, and the subsequent inability to accomplish the necessary repairs of the W.E. 4A Wave Analyzer, no intermodulation distortion data was obtained on the AN/TTC-15.

2.4.4.7 NOISE

Noise measurements taken on random trunks of the AN/TTC-15 SN 3 showed the noise level to be below 17 dba (-68 dbm), the sensitivity of the instrumentation described in the test procedures of Annex A.

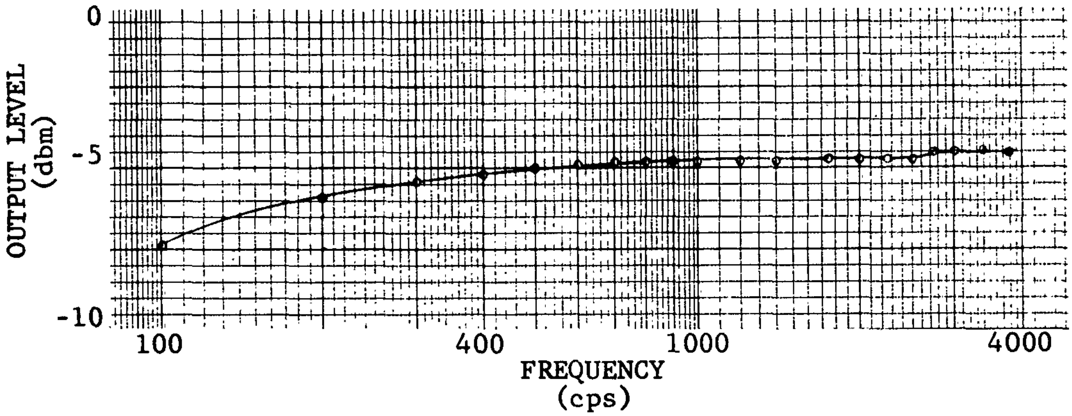


FIGURE B-77

FREQUENCY RESPONSE - AN/TTC-15 SN 3
Statistically Derived
Input Level -4 dbm

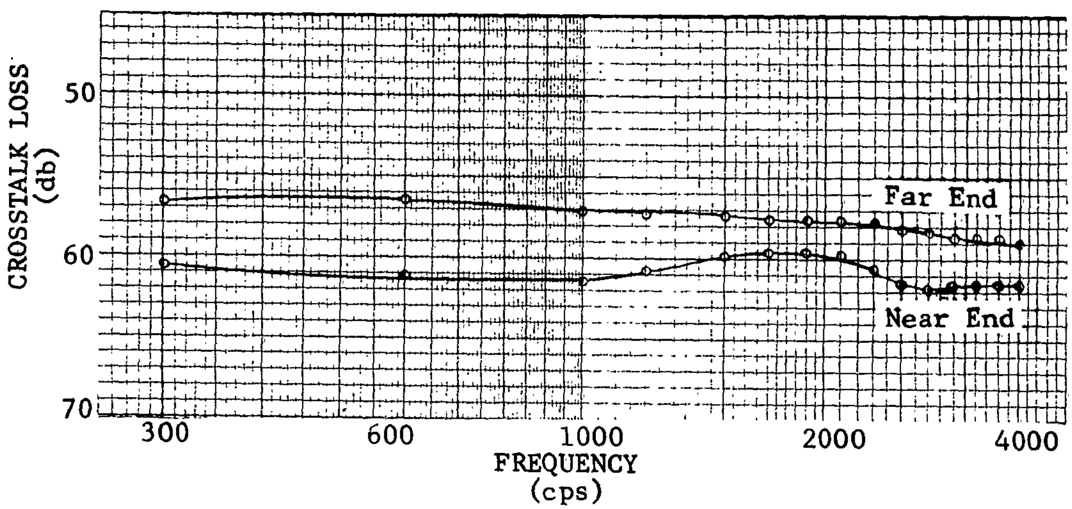


FIGURE B-78

CROSSTALK LOSS - AN/TTC-15 SN 3
SAME TIME SLOT - ADJACENT HIGHWAY
Statistically Derived
Input Level -4 dbm

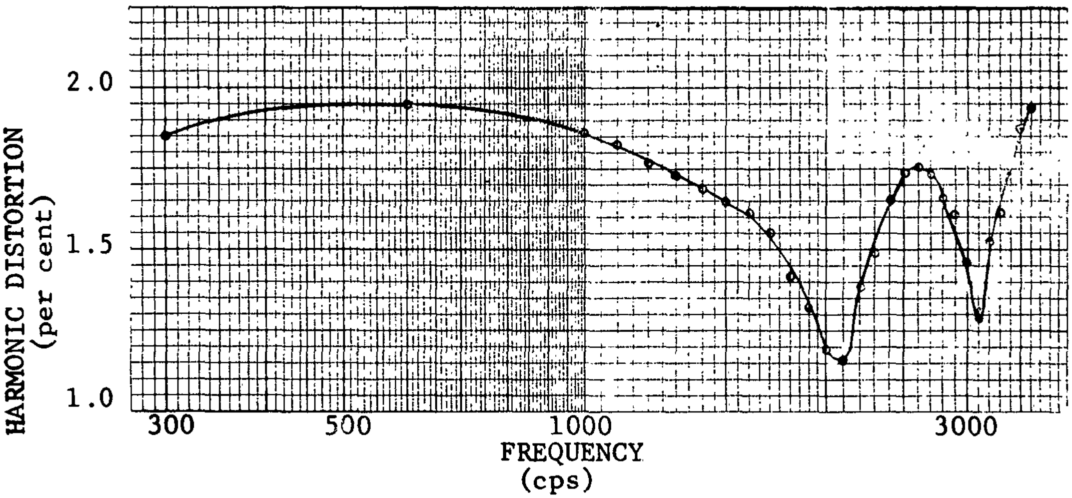


FIGURE B-79

HARMONIC DISTORTION - AN/TTC-15 SN 3
Statistically Derived
Input Level -4 dbm

2.4.4.8 PHASE DISTORTION

The envelope delay time was determined on random trunk to trunk combinations of the AN/TTC-15 SN 3 using the Phazor 200 AB. A plot of the data obtained is shown in Figure B-80. Due to the instrumental accuracy of the Phazor 200 AB (1.0°) the data presented is only indicative in nature. A plot of the absolute time delay is shown in Figure B-81.

2.4.4.9 LONGITUDINAL BALANCE

The longitudinal balance measured on the AN/TTC-15 SN 3 between random trunk combinations averaged more than 72 db below the reference signal level. Table B-45 presents a tabulation of the data obtained.

2.4.4.10 LIMITING

Limiting was measured on random trunk to trunk combinations of the AN/TTC-15 SN 3. Figure B-82 is a plot of the most probable mean of limiting over the range of input levels from -12 to +12 dbm. Absolute limiting is observed at +4.0 dbm output. The statistical range of the means was well under 0.2 db and hence was not plotted on the figure.

2.4.4.11 CARRIER LEVEL

The level of the 12.5 Kcps carrier (TDM sampling rate) was measured on random trunk to trunk combinations on AN/TTC-15 SN 3. Table B-46 presents a tabulation of carrier levels measured on 10 trunk to trunk combinations. All trunks tested showed carrier levels to be lower than 57.0 dbm.

Carrier levels were not measured for the 400 Kcps master clock frequency due to the unavailability of R.F. wave analyzer equipment.

2.4.4.12 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits in the AN/TTC-15 SN 1, 2 and 3. Figures B-83 through B-88 show the sensitivity and selectivity of the detectors in SN 3. The sensitivities of the detectors range from -21 to -42 dbm.

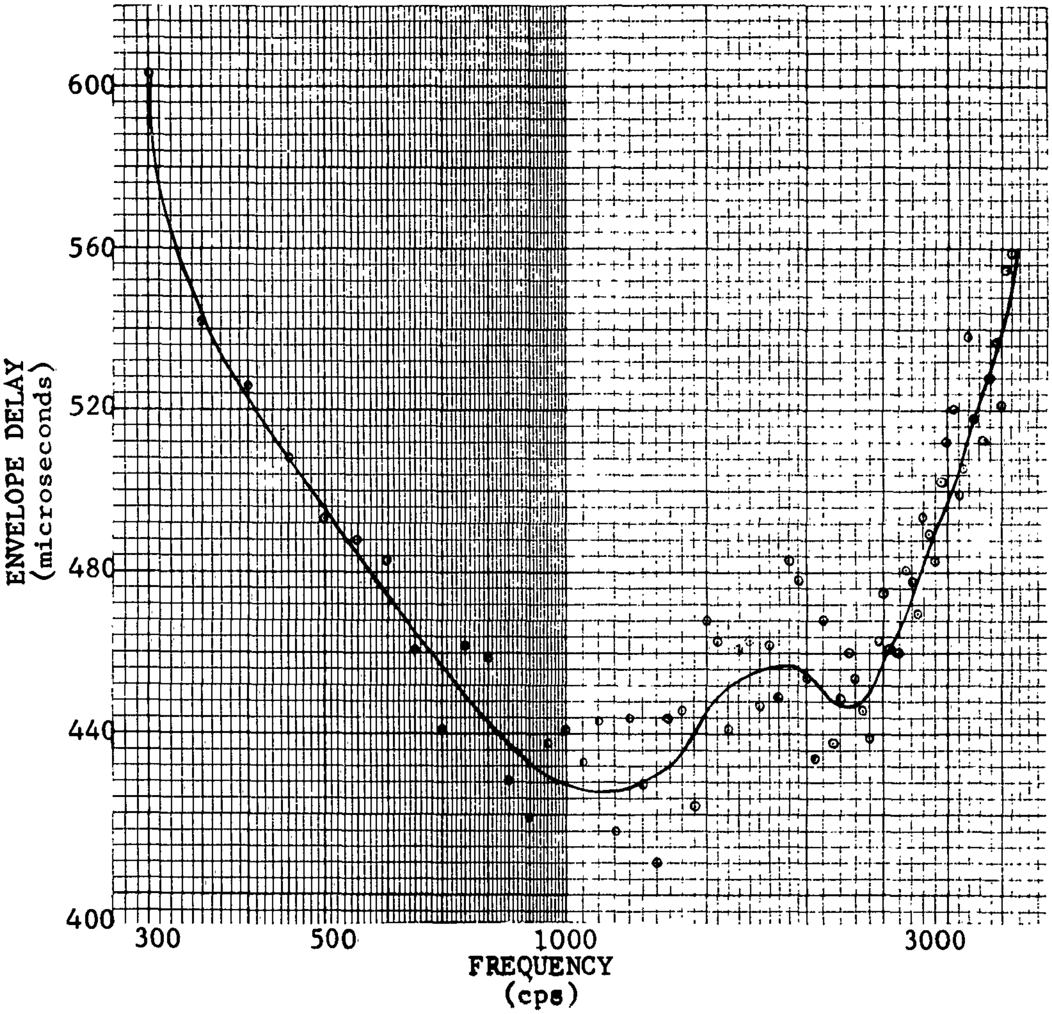


FIGURE B-80

ENVELOPE DELAY - AN/TTC-15 SN 3
Statistically Derived
Input Level -4 dbm

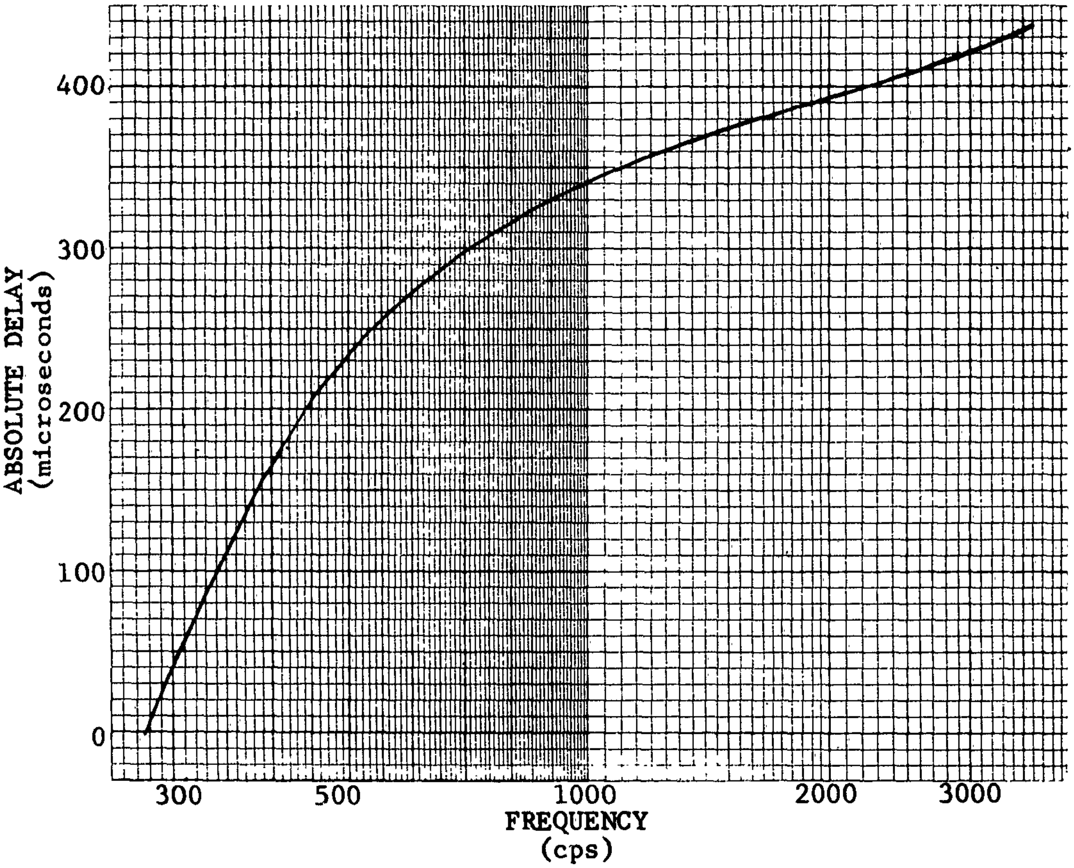


FIGURE B-81

ABSOLUTE PHASE DELAY - AN/TTC-15 SN 3
Statistically Derived
Input Level -4 dbm

TABLE B-45

LONGITUDINAL BALANCE - AN/TTC-15
Trunks Tested 10

LOCAL TRUNK	TIE TRUNK	LINK	LEVEL	LONGITUDINAL BALANCE (db)
C-4	C-13	52	6	72.6
E-6	H-12	19	7	69.5
J-4	C-9	34	8	68.8
K-6	C-11	48	6	74.4
B-8	C-12	63	7	72.7
C-7	E-15	22	9	71.1
F-7	C-14	15	9	74.1
H-8	G-14	24	9	71.7
J-3	H-14	30	9	72.5
B-5	K-15	32	9	74.7

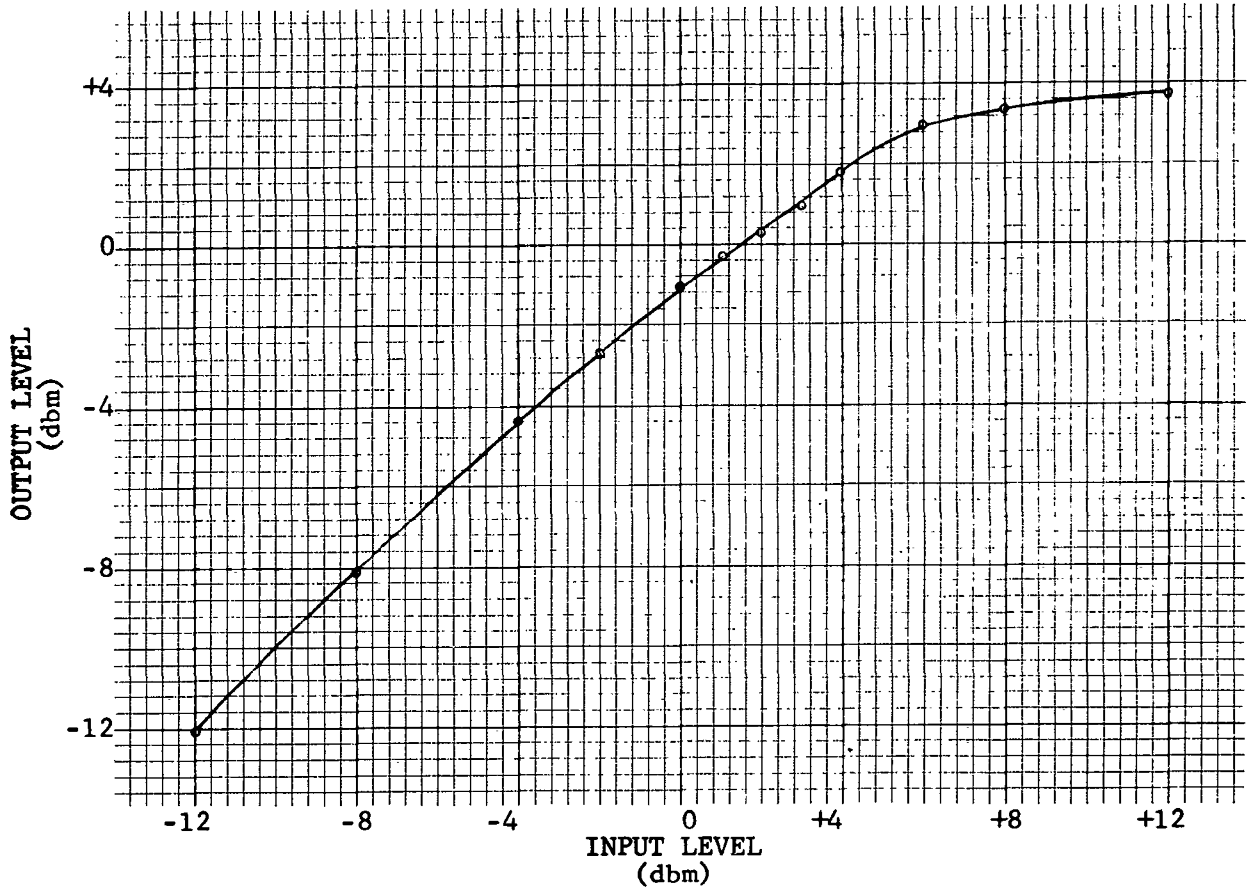


FIGURE B-82

LIMITING - AN/TTC-15 SN 3
Statistically Derived

TABLE B-46

CARRIER LEVEL - AN/TTC-15 SN 3
Trunks Tested 10

LOCAL TRUNK	TIE TRUNK	LINK	CARRIER LEVEL (dbm)
E-3	B-12	56	-67.0
B-1	E-12	69	-69.5
J-6	A-10	60	-64.5
A-8	B-9	18	-67.0
E-2	B-10	42	-67.0
G-5	* A-14	32	-66.0
F-5	* A-15	70	-80.0
B-7	* C-15	14	-68.0
G-1	* G-14	63	-57.0
H-6	* B-15	40	-64.5

*NOTE: Long distance tie trunks

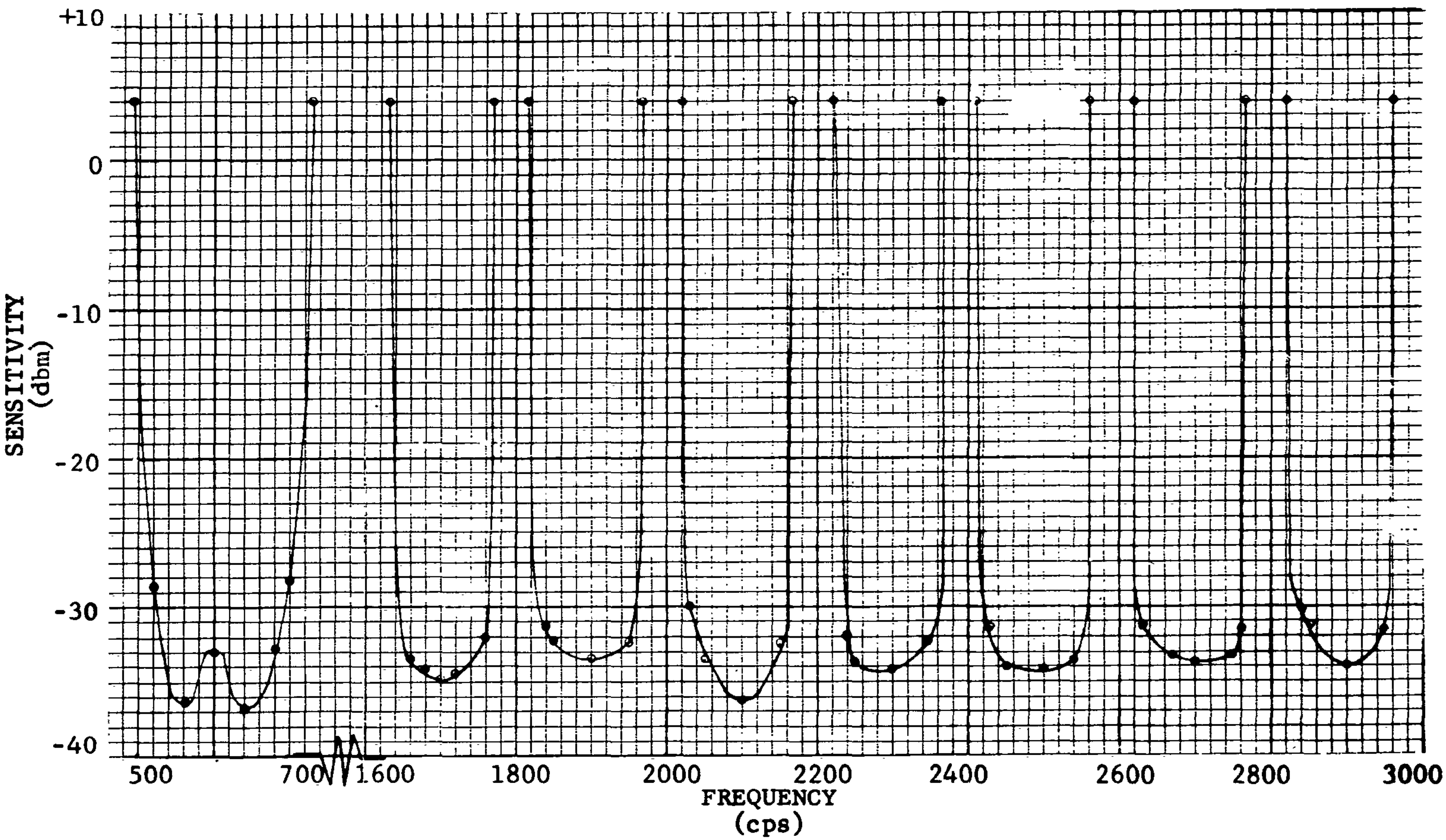


FIGURE B-83

PRIMARY REGISTER MFSD SELECTIVITY CURVES - AN/TTC-15 SN 3
Registers Tested 3

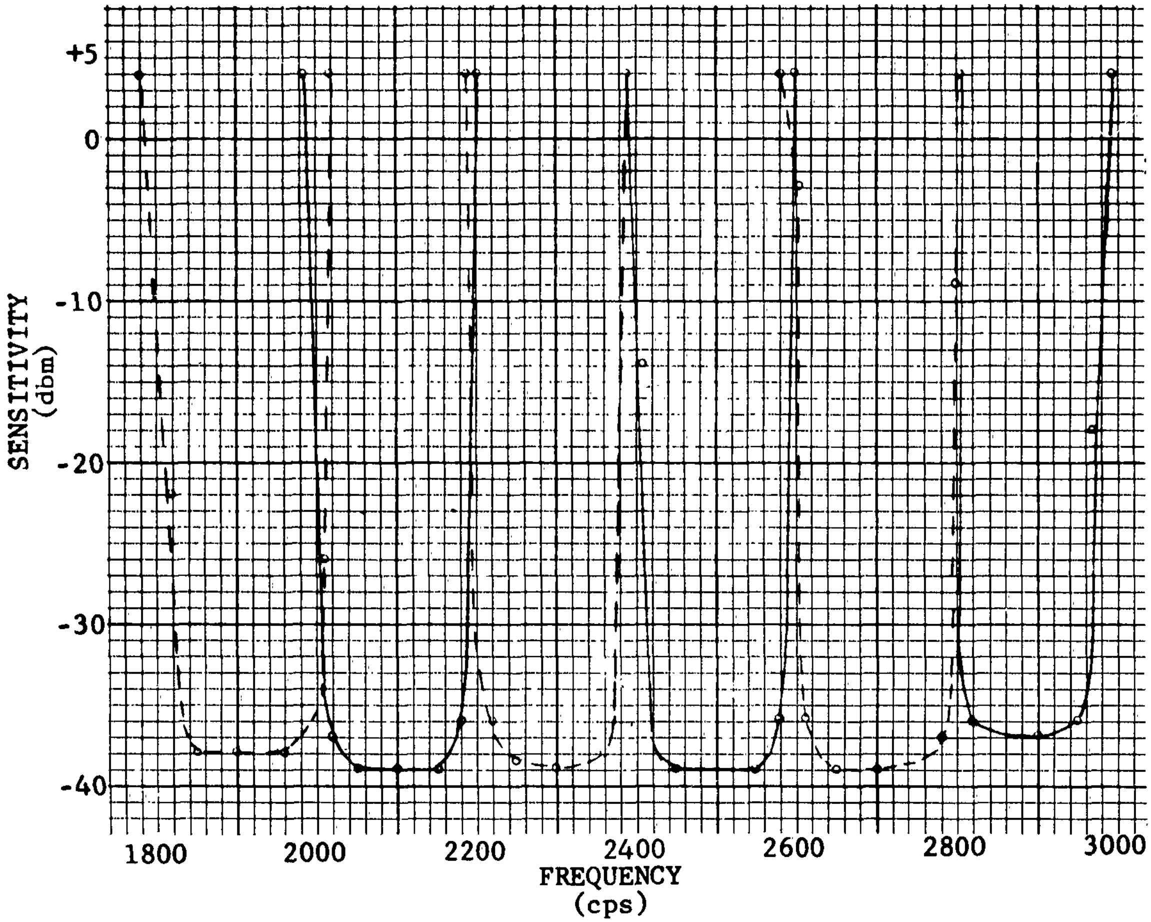


FIGURE B-84

RELEASE AND RECALL SELECTIVITY CURVES
AN/TTC-15 SN 3

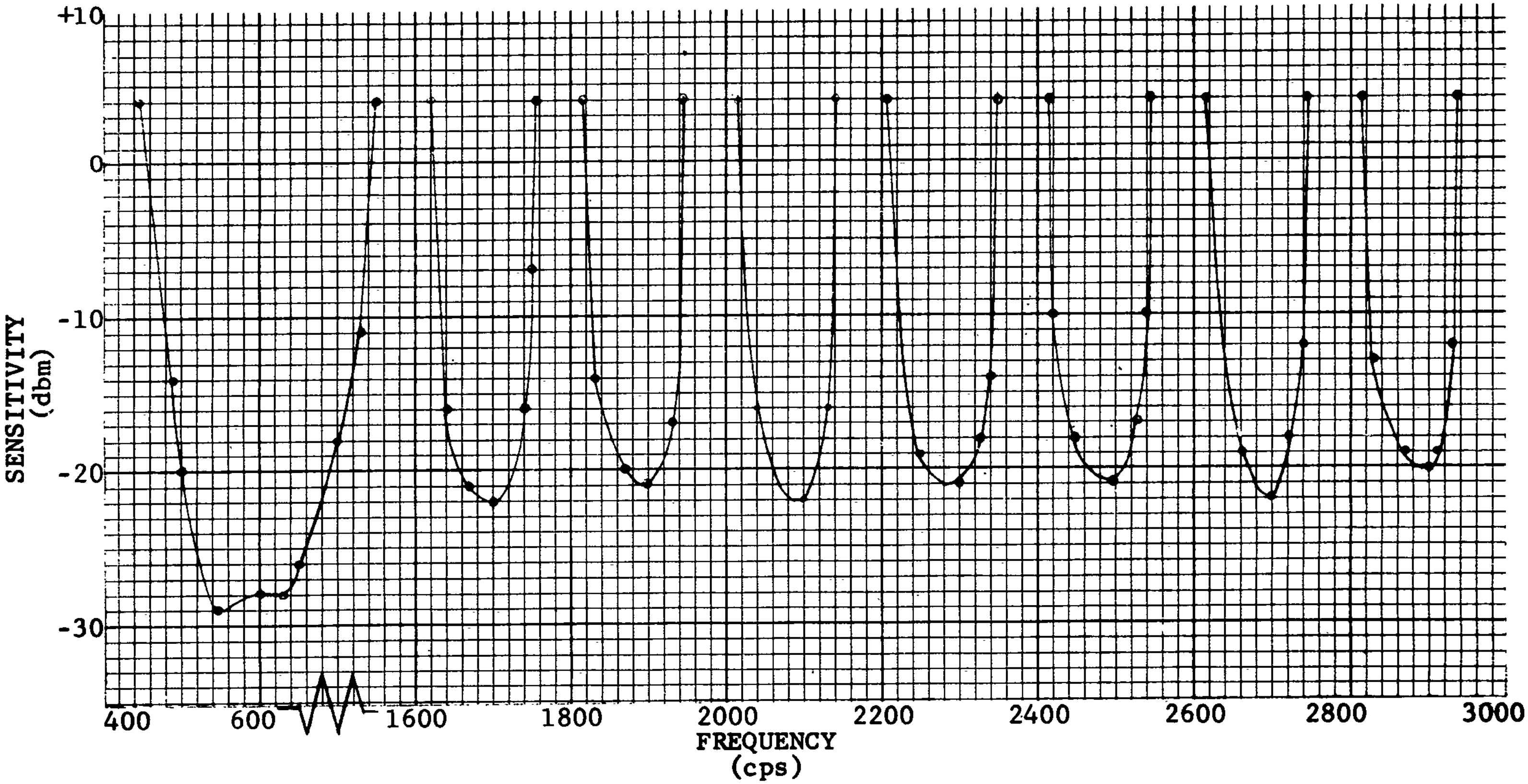


FIGURE B-85

ROUTINE TEST CIRCUIT SELECTIVITY CURVE - AN/TTC-15 SN 3

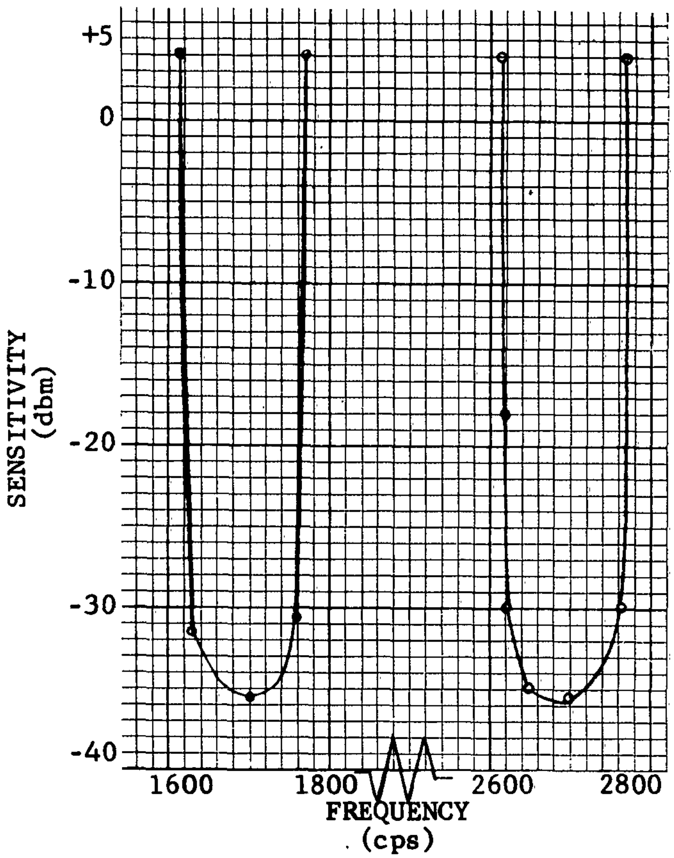


FIGURE B-86

ROUTE SELECTOR SELECTIVITY CURVES
AN/TTC-15 SN 3

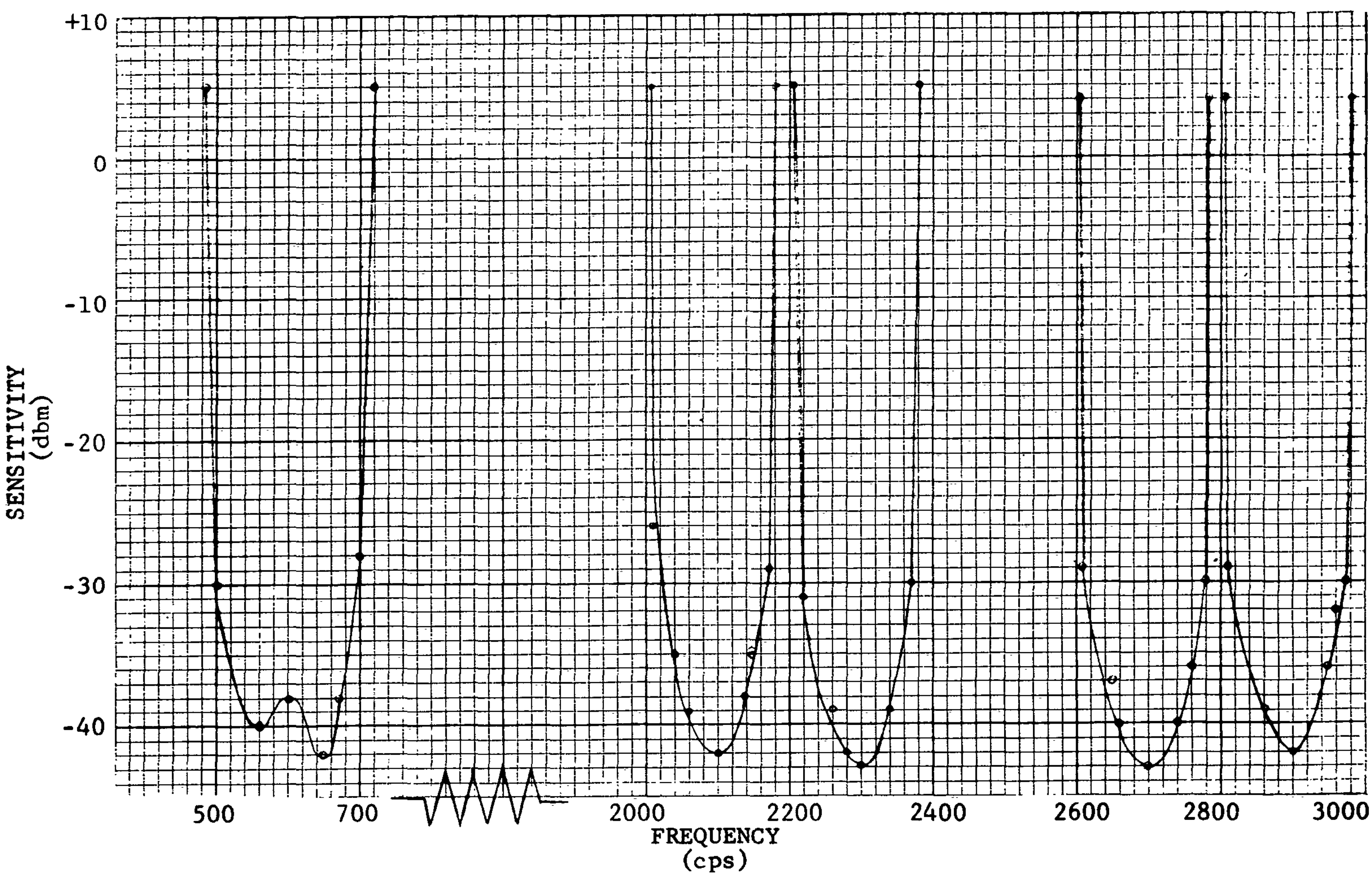


FIGURE B-87

TEST TONE ANSWERING CIRCUIT SELECTIVITY CURVES - AN/TTC-15 SN 3

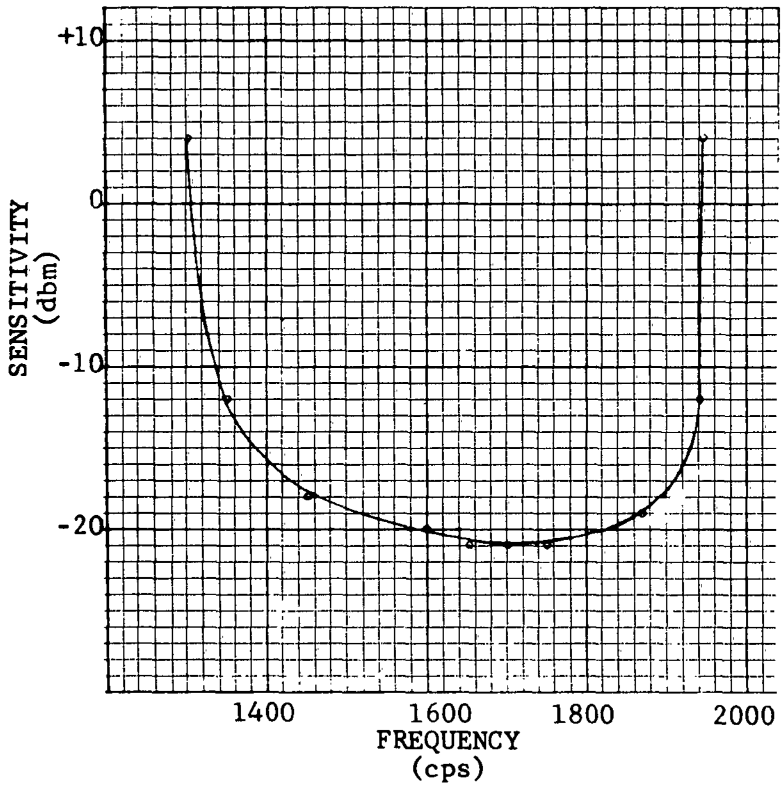


FIGURE B-88

VOICE MONITOR SELECTIVITY CURVE - AN/TTC-15 SN 3

Figures B-89 and B-90 show plots of sensitivity and selectivity for the primary register tone detector circuits in SN 1 and SN 2.

2.4.4.13 TONE GENERATOR OUTPUT

The frequency and power output of the several tone generators of AN/TTC-15 SN 3, SN 1 and SN 2 were measured. The data obtained, measured at the output terminal of the central, are tabulated in Tables B-47 through B-49.

2.4.4.14 SIGNAL TO NOISE AND SIGNAL TO SIGNAL

Signal to noise and signal plus noise to noise versus total signal ratios were measured on the AN/TTC-15 SN 1 and SN 2.

For accuracy at the low signal levels used in this test, S/N and $\frac{S+N}{N}$ ratios were determined using millivolt measurements.

Plots showing the effect of noise upon the sensitivity of detector circuitry of AN/TTC-15 SN 1 and SN 2 are shown in Figures B-91 through B-98.

Signal to signal ratios versus total signal measurements taken on AN/TTC-15 SN 1 and SN 2 are shown in Figures B-99 and B-100.

2.5 TEST OF TA-375/TTC TELEPHONE SIGNAL CONVERTER

2.5.1 GENERAL DESCRIPTION OF EQUIPMENT

The TA-375 converter is a transportable, lightweight, transistorized four-channel converter.

2.5.2 OPERATIONAL DESCRIPTION

The TA-375 converter is called a ring-down converter designed to connect existing operational military switchboards and four wire electronic switching centers.

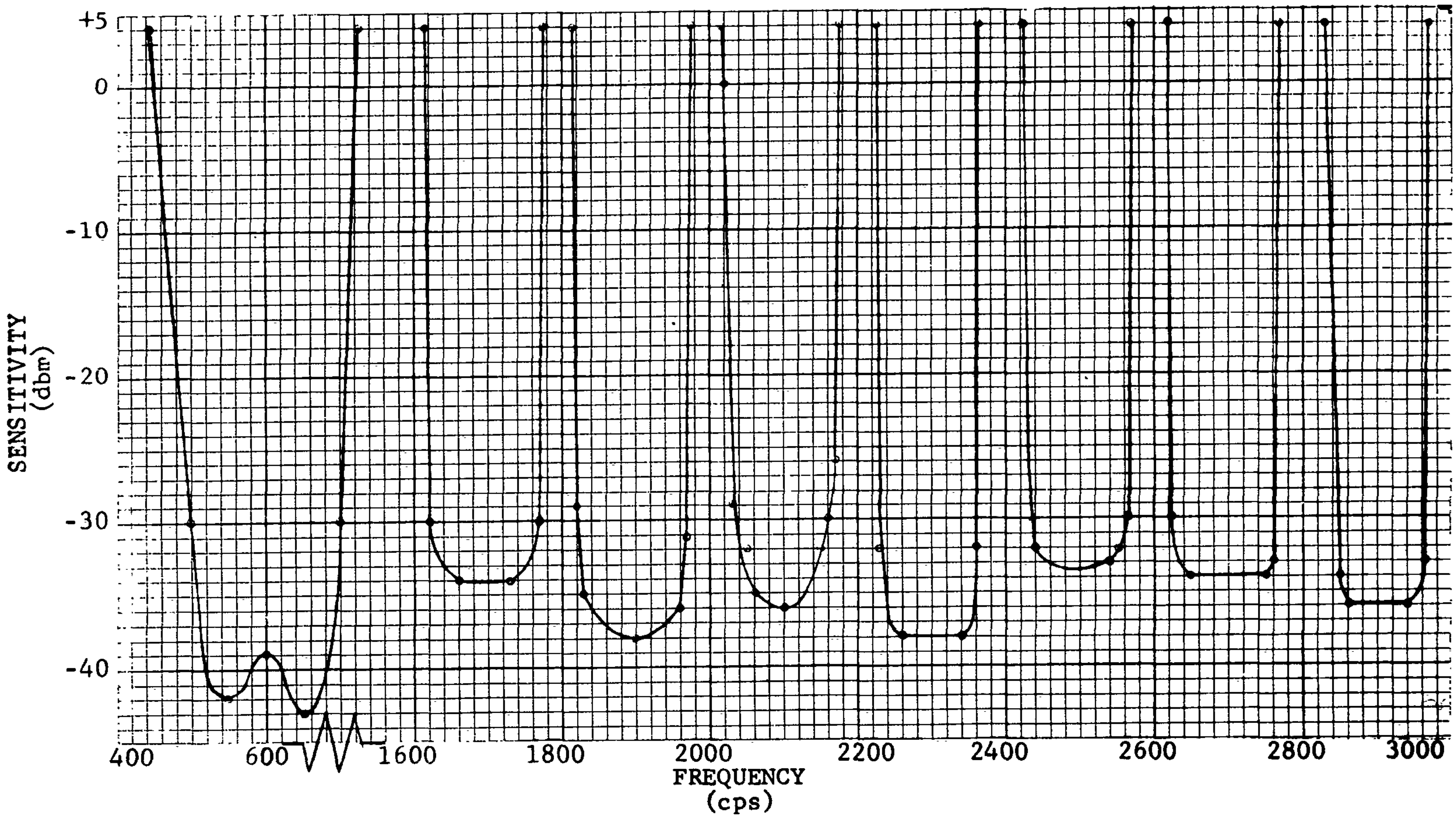


FIGURE B-89

PRIMARY REGISTER MFSD SELECTIVITY CURVES
AN/TTC-15 SN 1

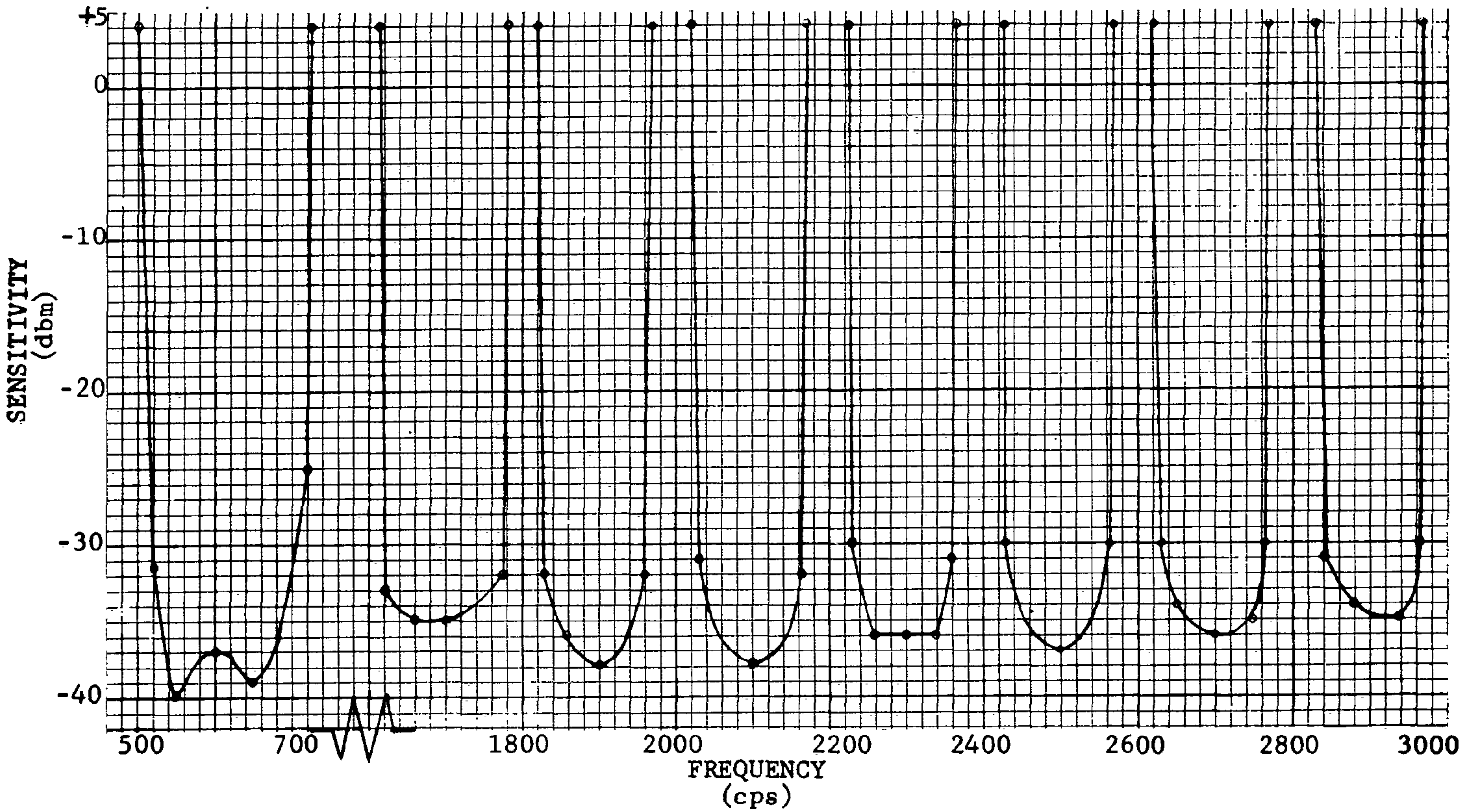


FIGURE B-90

PRIMARY REGISTER MFSD SELECTIVITY CURVES
AN/TTC-15 SN 2

TABLE B-47

TONE GENERATOR OUTPUT - AN/TTC-15 SN 3

TONE GENERATORS	FREQUENCY (cps)	SIGNAL LEVEL (dbm)
600	600	-19.3
1700	1700	-17.2
1900	1900	-17.9
2100	2101	-17.4
2300	2300	-18.1
2500	2500	-18.8
2700	2700	-17.7
2900	2902	-17.7
All Trunks Busy	600	Defective Circuit
Line Busy	600	-21.2
Ring Forward	600	+ 5.8
Ring Back	600	-19.1

TABLE B-48

TONE GENERATOR OUTPUT AN/TTC-15 SN 1

TONE GENERATORS	FREQUENCY (cps)	SIGNAL LEVEL (dbm)
600	602	-18.4
1700	1702	-17.4
1900	1901	-18.7
2100	2103	-18.4
2300	2303	-19.1
2500	2505	-18.8
2700	2705	-19.0
2900	2905	-17.7
All Trunks Busy	602	-18.0
Line Busy	602	-21.9
Ring Forward	602	+ 6.32
Ring Back	602	-21.9

TABLE B-49

TONE GENERATOR OUTPUT AN/TTC-15 SN 2

TONE GENERATORS	FREQUENCY (cps)	SIGNAL LEVEL (dbm)
600	602	-19.6
1700	1702	-17.2
1900	1901	-18.2
2100	2102	-18.2
2300	2305	-18.3
2500	2503	-18.3
2700	2705	-18.0
2900	2905	-17.4
All Trunks Busy	602	-16.1
Line Busy	602	-20.9
Ring Forward	602	+ 5.7
Ring Back	602	-23.4

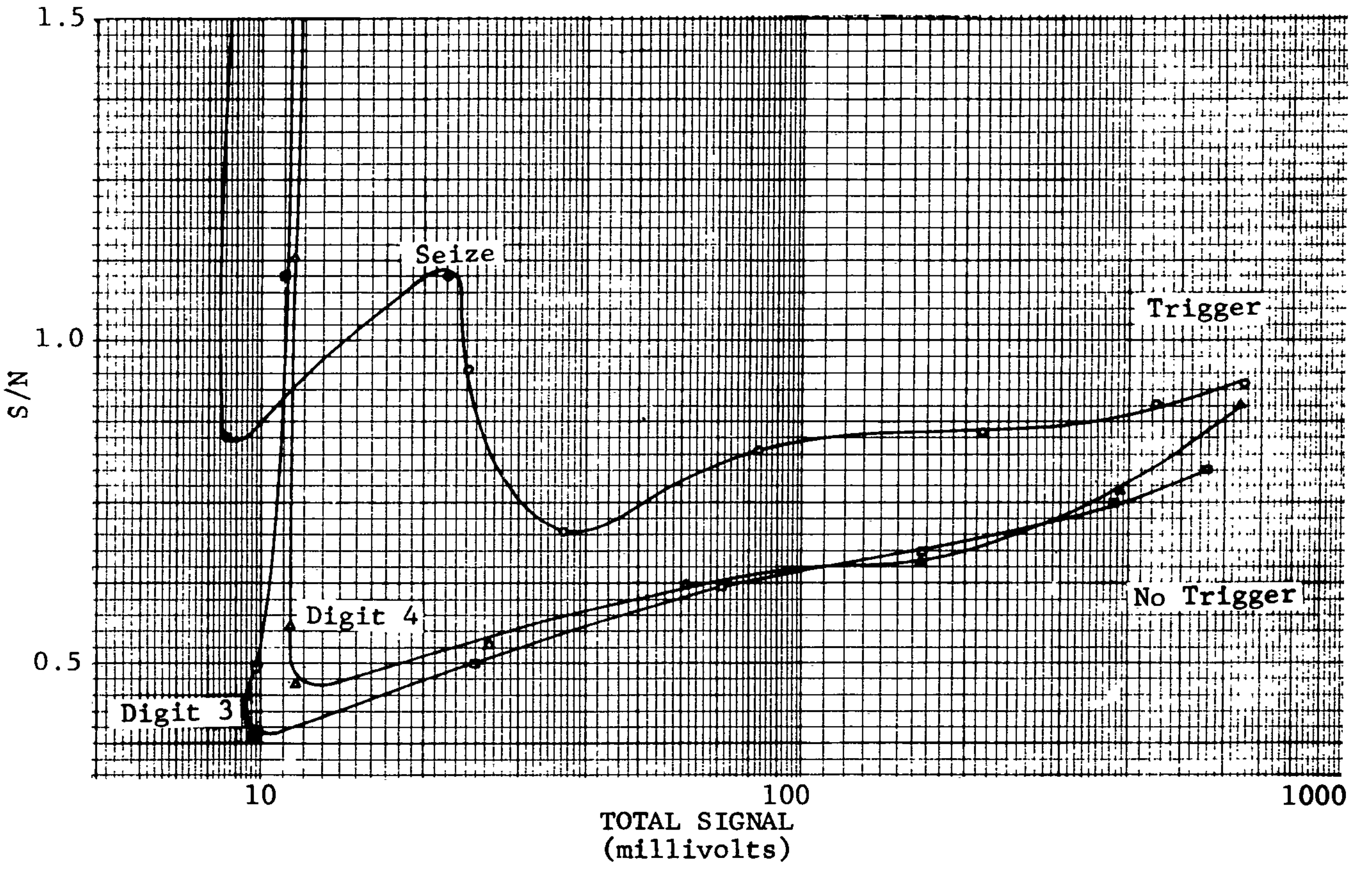


FIGURE B-91

SEIZE, DIGIT 3 AND DIGIT 4

SIGNAL TO NOISE $\frac{S}{N}$ VERSUS TOTAL SIGNAL

AN/TTC-15 SN 1

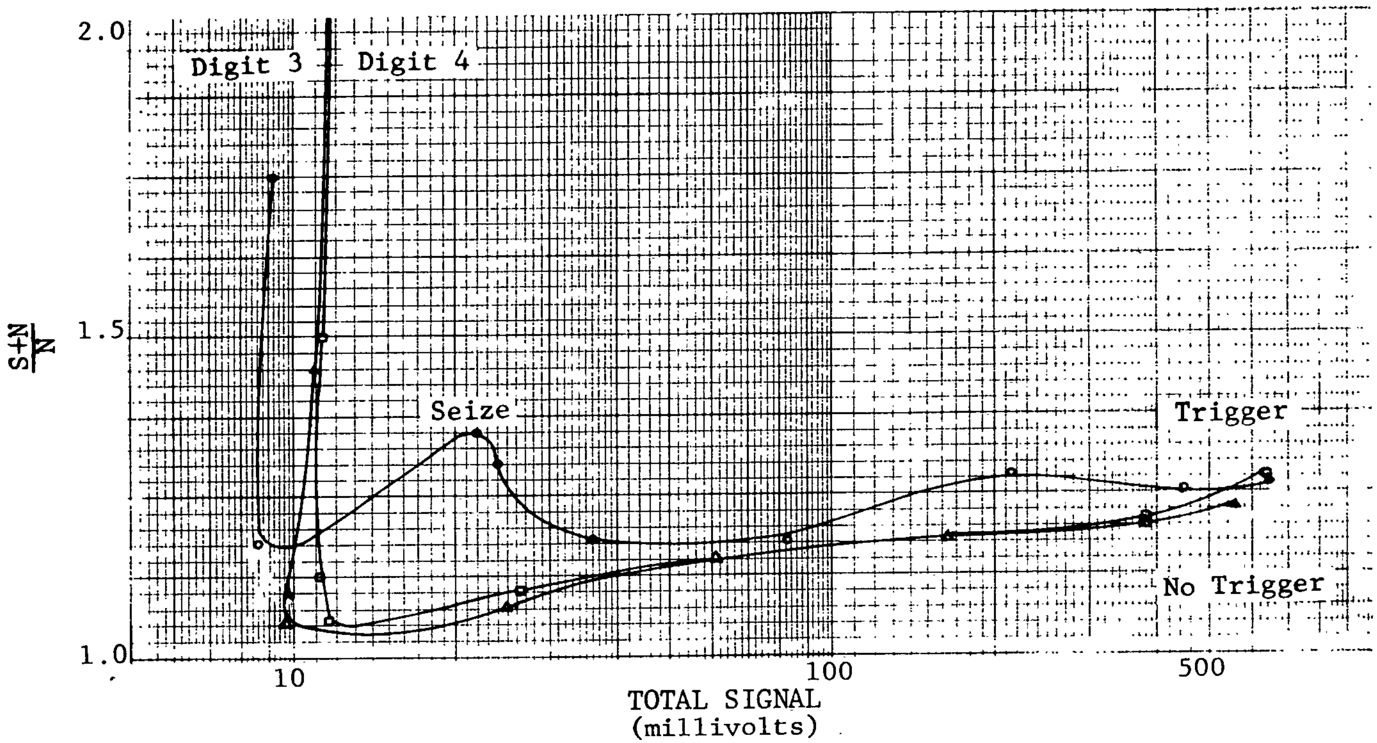


FIGURE B-92

SEIZE, DIGIT 3 AND DIGIT 4

SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL

AN/TTC-15 SN 1

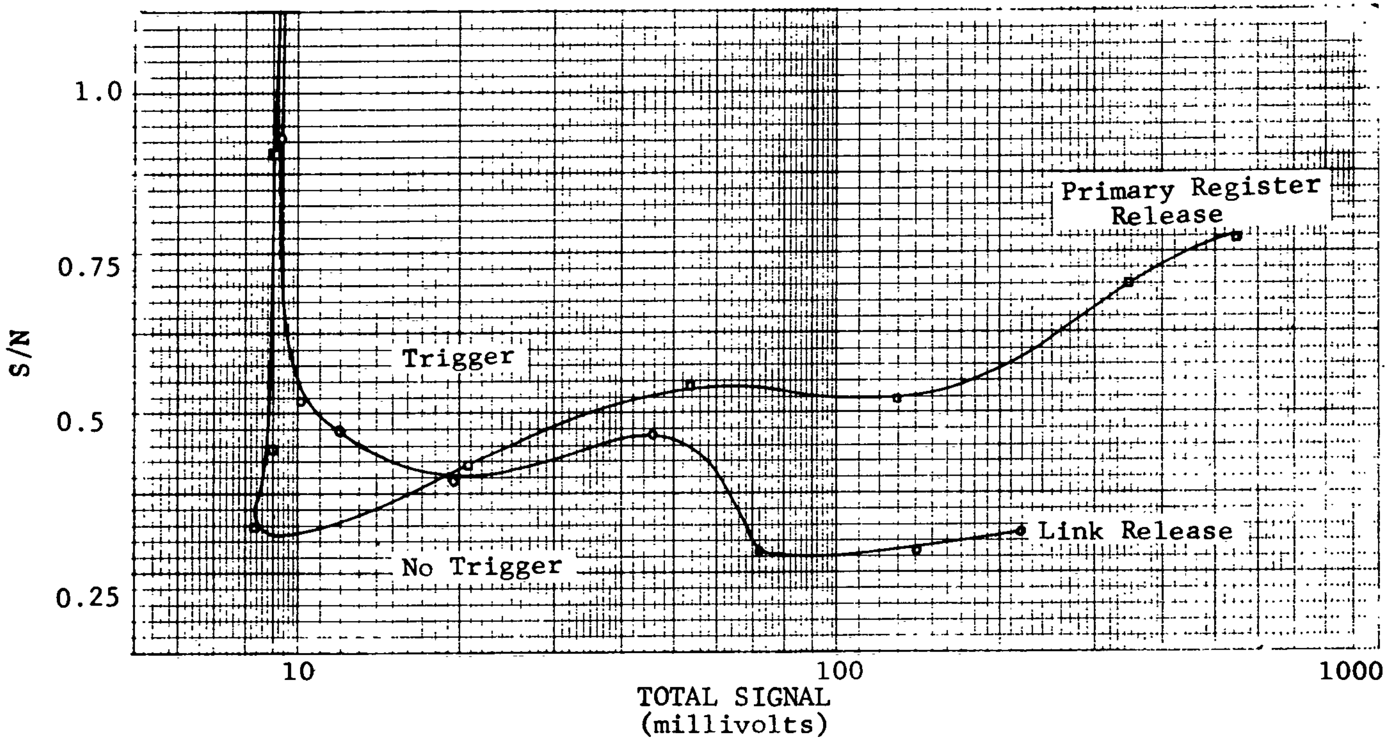


FIGURE B-93

REGISTER RELEASE AND LINK RELEASE

SIGNAL TO NOISE $\frac{S}{N}$ VERSUS TOTAL SIGNAL

AN/TTC-15 SN 1

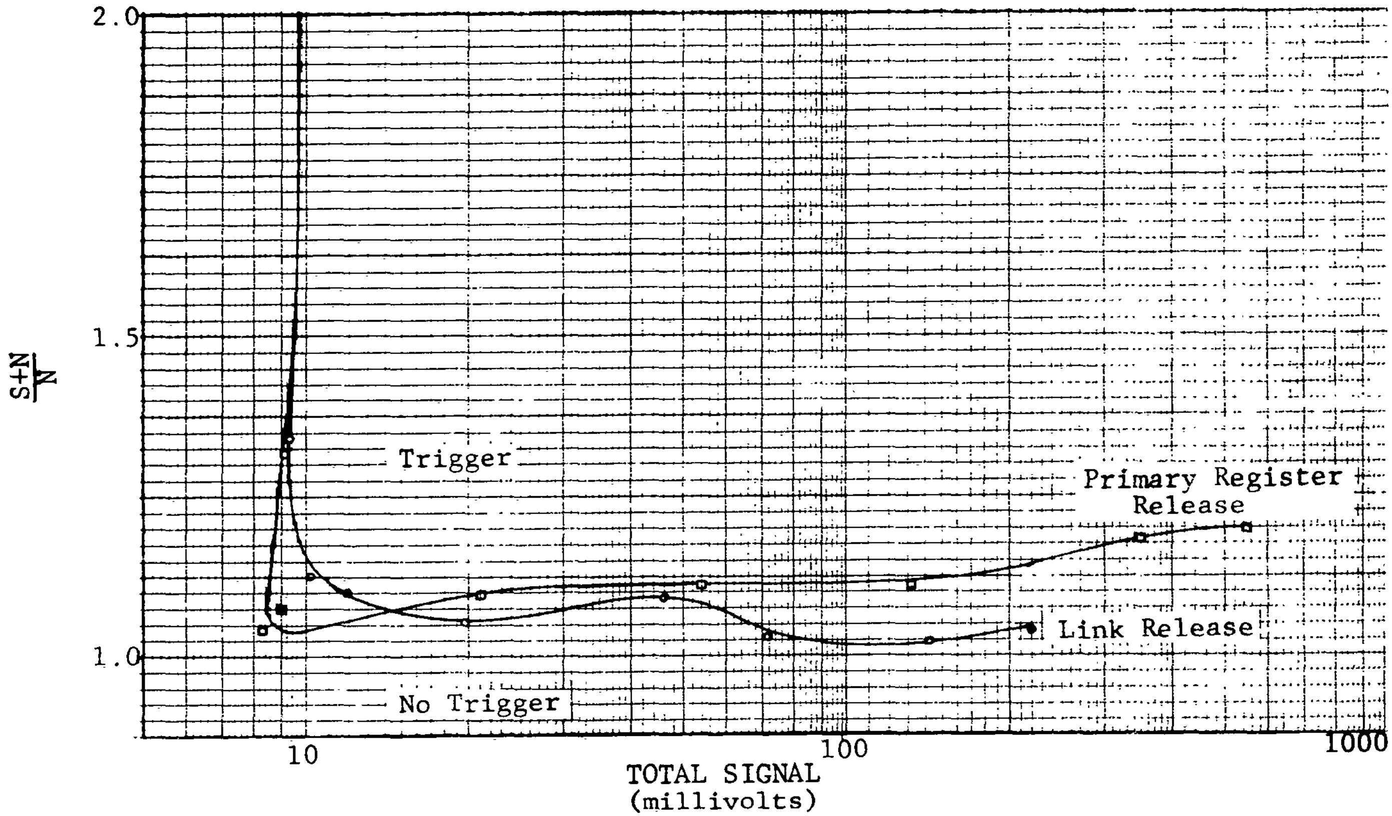


FIGURE B-94

REGISTER AND LINK RELEASE

SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL

AN/TTC-15 SN 1

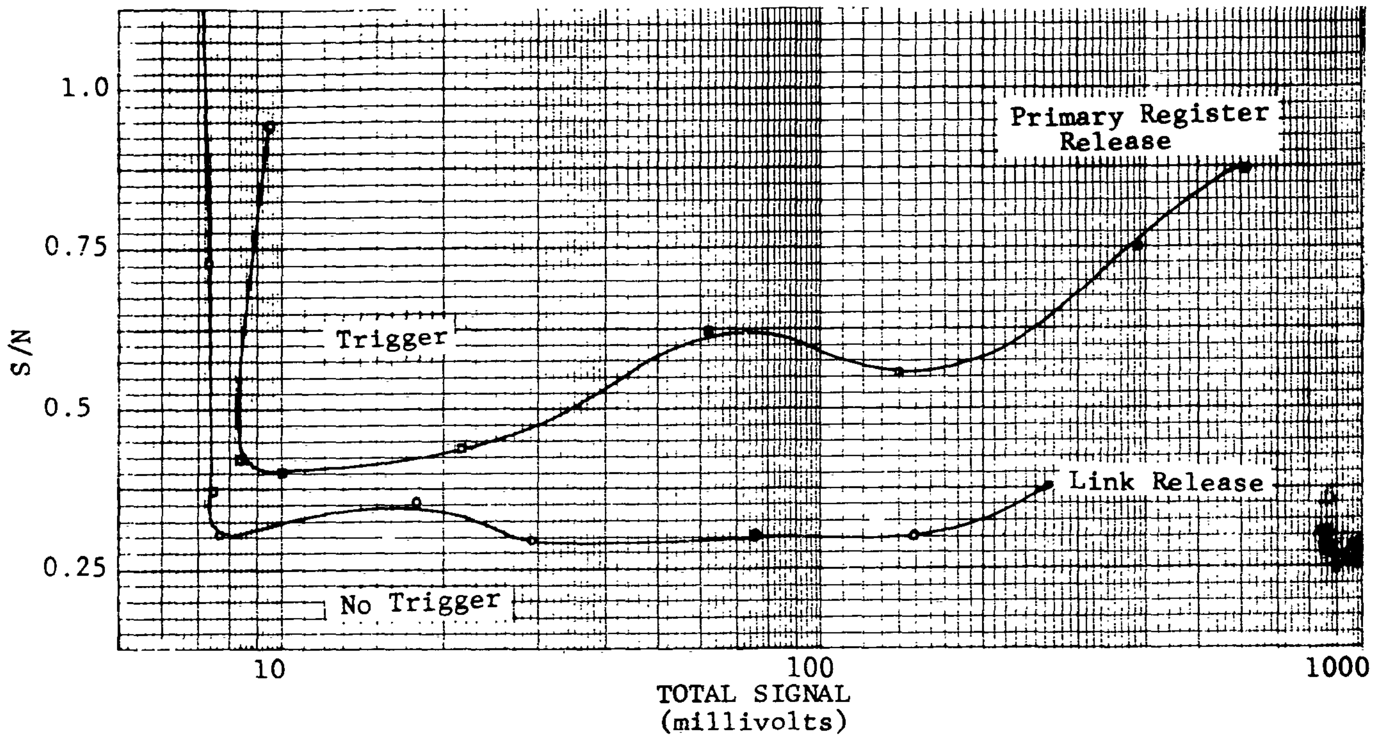


FIGURE B-95

LINK AND REGISTER RELEASE
SIGNAL TO NOISE (S/N) VERSUS TOTAL SIGNAL
AN/TTC-15 SN 2

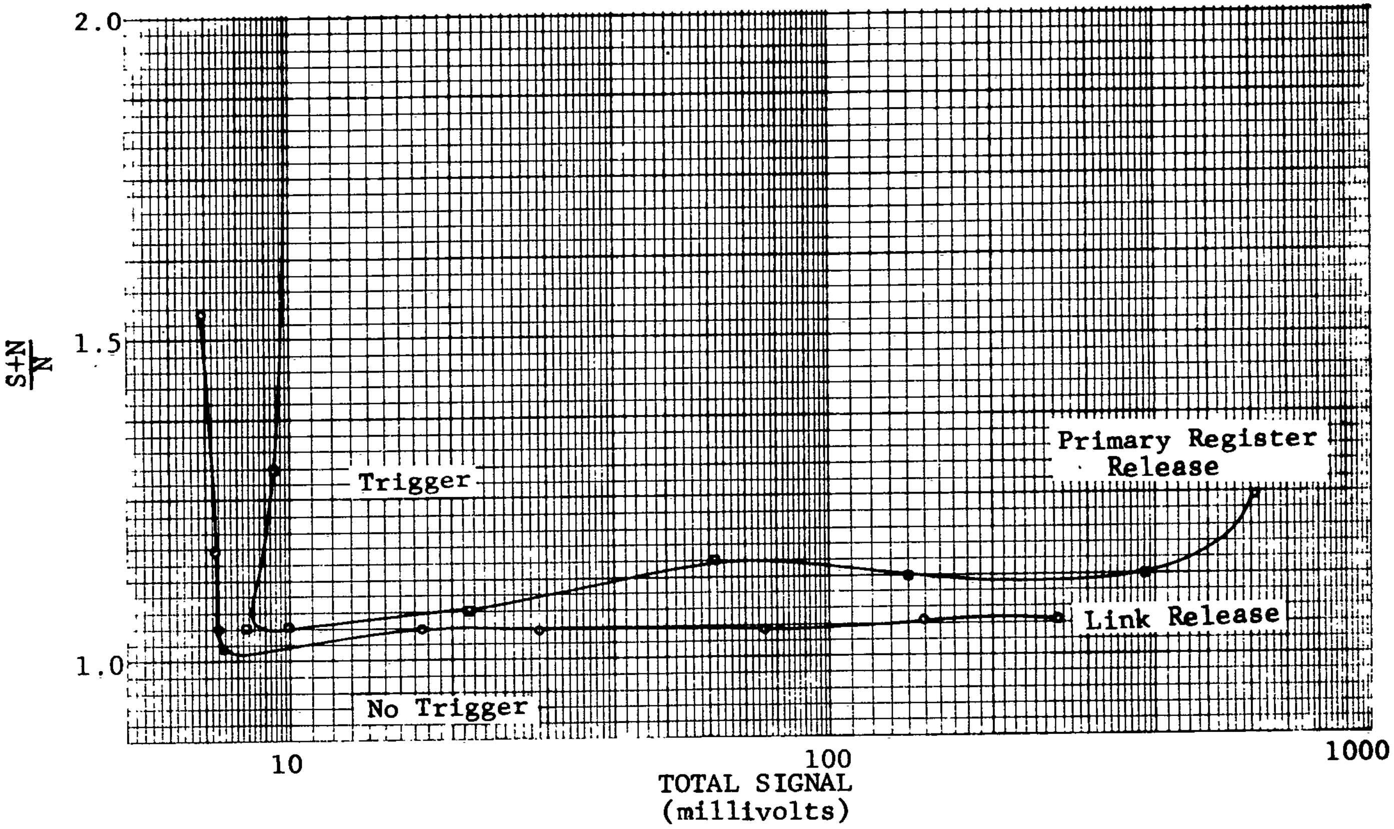


FIGURE B-96

LINK AND REGISTER RELEASE

SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-15 SN 2

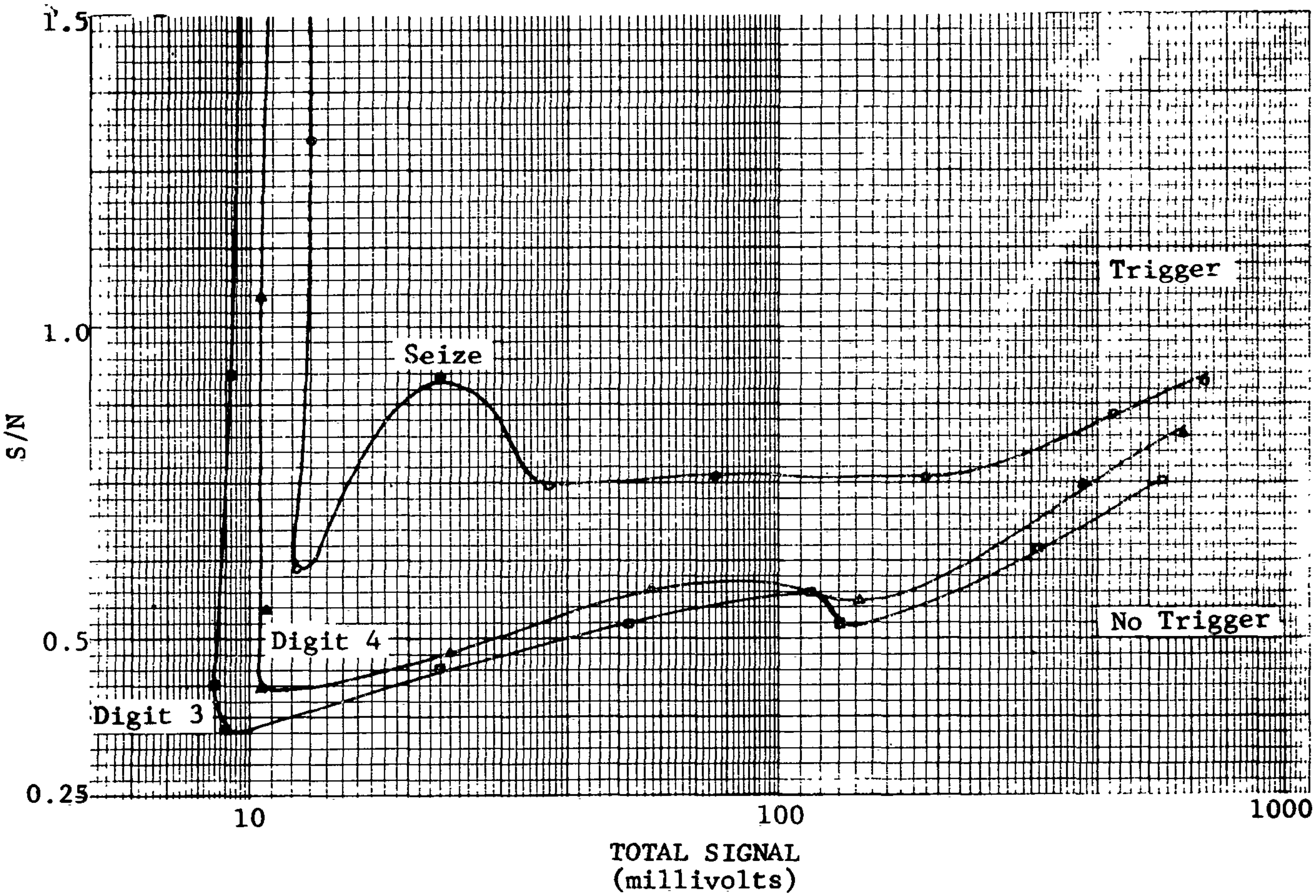


FIGURE B-97

SEIZE, DIGIT 3 AND DIGIT 4
SIGNAL TO NOISE $\frac{S}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-15 SN 2

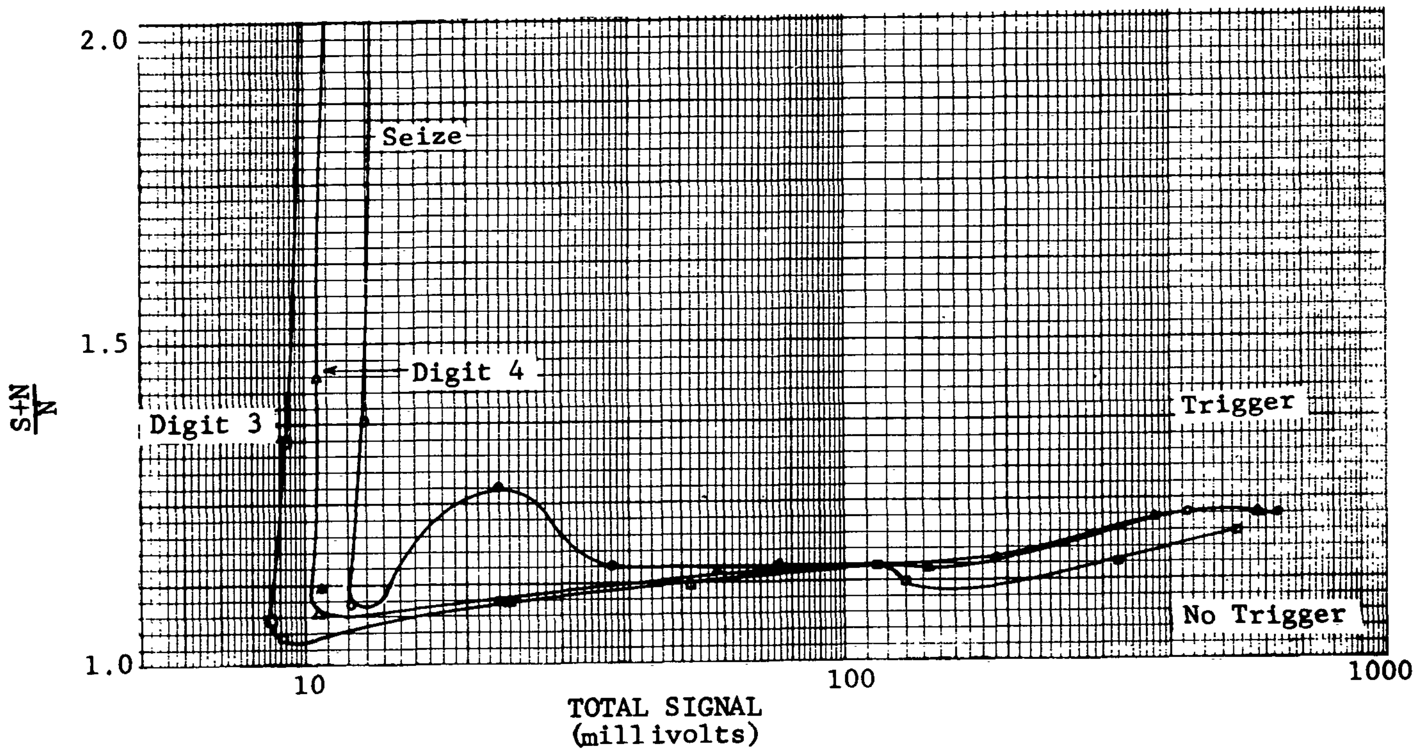


FIGURE B-98

SEIZE, DIGIT 3 AND DIGIT 4
SIGNAL PLUS NOISE TO NOISE $\frac{S+N}{N}$ VERSUS TOTAL SIGNAL
AN/TTC-15 SN 2

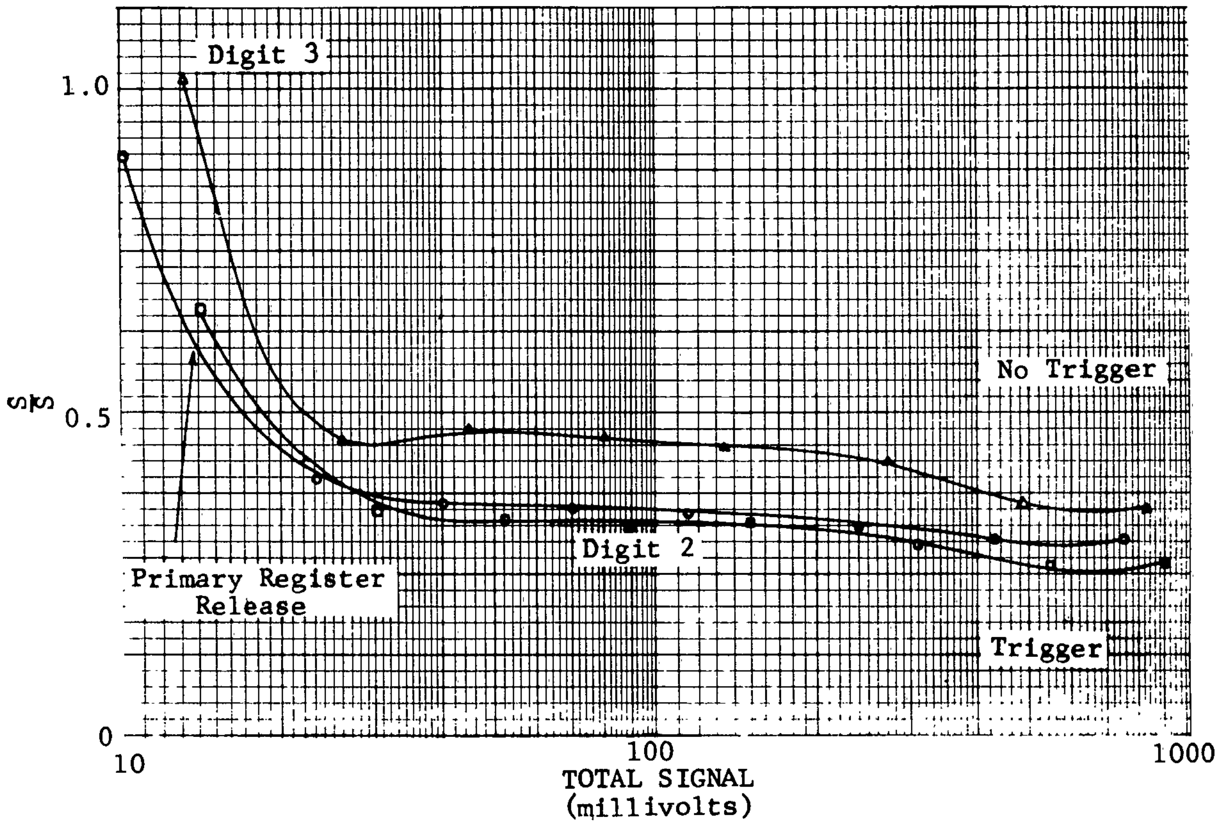


FIGURE B-99

DIGIT 3 AND RELEASE

SIGNAL TO SIGNAL $\frac{S_1}{S_2}$ VERSUS TOTAL SIGNAL

AN/TTC-15 SN 1

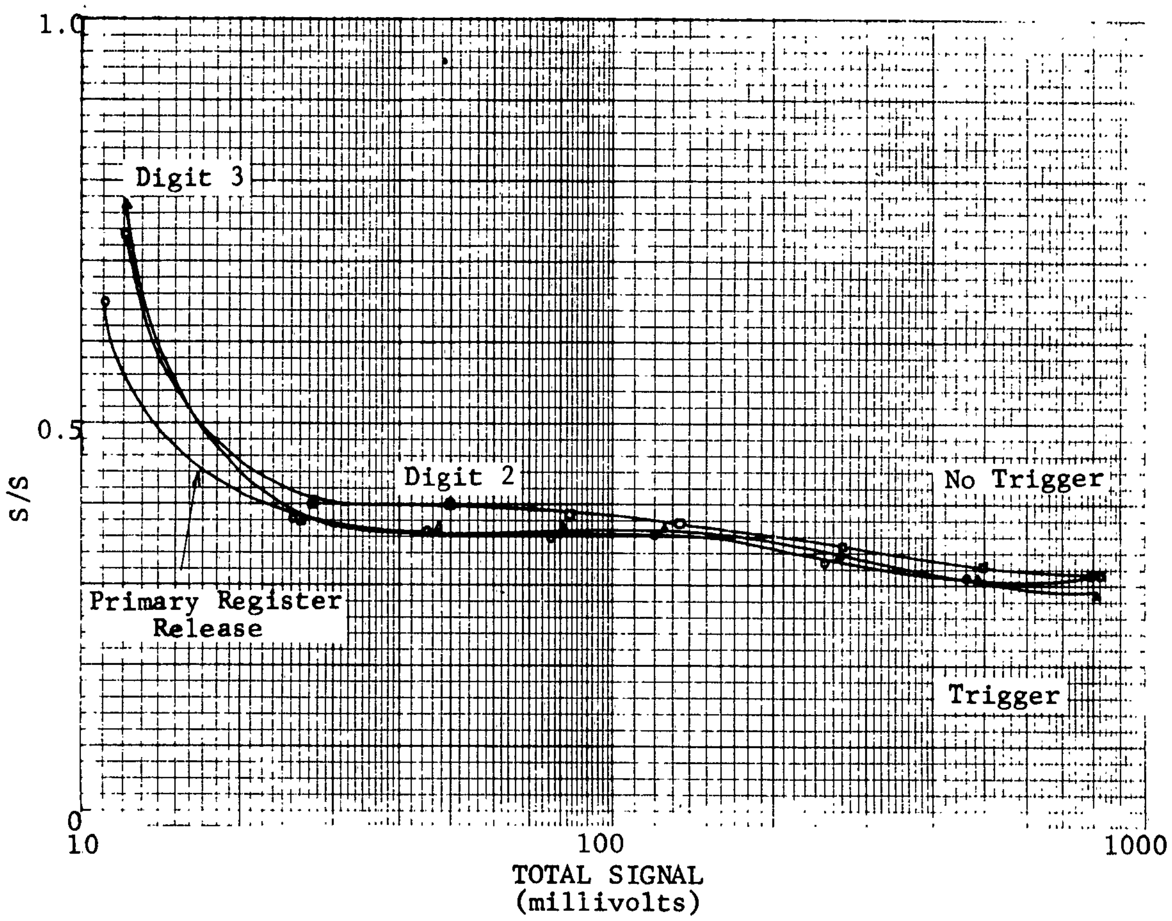


FIGURE B-100

RELEASE, DIGIT 2 AND DIGIT 3
SIGNAL TO SIGNAL $\frac{S_1}{S_2}$ VERSUS TOTAL SIGNAL
AN/TTC-15 SN 2

2.5.3 TECHNICAL DESCRIPTION

The TA-375 has the following characteristics:

Circuit Capacity	4 Channels
Input power	+12 volts dc or 115/230 volts ac 50/60 cps single phase
Signalling frequencies	
Transmit	1600,1700,1900, 2100,2500,2700, 2900 cps
Receive	1600,1700,2700 2900 cps

2.5.4 TEST RESULTS - TA-375/TTC TELEPHONE SIGNAL CONVERTER

Transmission measurements were not made on this equipment since it is a straight through metallic circuit and preliminary observations of response, distortion and crosstalk indicated insignificant variations or levels.

2.5.4.1 TONE GENERATOR OUTPUT

The frequency and power output of the several tone generators of the TA-375/TTC SN 1 and SN 2 Telephone Signal Converter were measured. The data obtained are tabulated in Tables B-50 and B-51.

2.5.4.2 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits in TA-375/TTC SN 1 and SN 2. Figures B-101 and B-102 show the sensitivity and selectivity of the detectors in SN 1 and SN 2. The sensitivities of the detectors range from -41.5 to -38.5 dbm.

TABLE B-50

TONE GENERATOR OUTPUT - TA-375/TTC SN 1

TONE GENERATOR	FREQUENCY	OUTPUT SIGNAL LEVEL (dbm)
Seize - S	1703	-18.2
"O" Digit - U	1903	-17.3
X	2502	-17.4
Interlock - V	2100 *	-17.9
Z	2900 *	-17.4
Release - Y	2705	-17.6
Z	2900	-16.7
1600	1598	- 4.5

* 100 millisecond burst of VZ tones prevented the exact reading of the frequency with the counter

TABLE B-51

TONE GENERATOR OUTPUT - TA-375/TTC SN 2

TONE GENERATOR	FREQUENCY	OUTPUT SIGNAL LEVEL (dbm)
Seize - S	1704	-17.8
"O" Digit - U	1906	-18.1
X	2504	-16.3
Interlock - V	2100 *	-17.3
Z	2900 *	-14.6
Release - Y	2705	-18.0
Z	2900	-16.0
1600		- 4.6

* 100 millisecond burst of VZ tones prevented the exact reading of the frequency with the counter

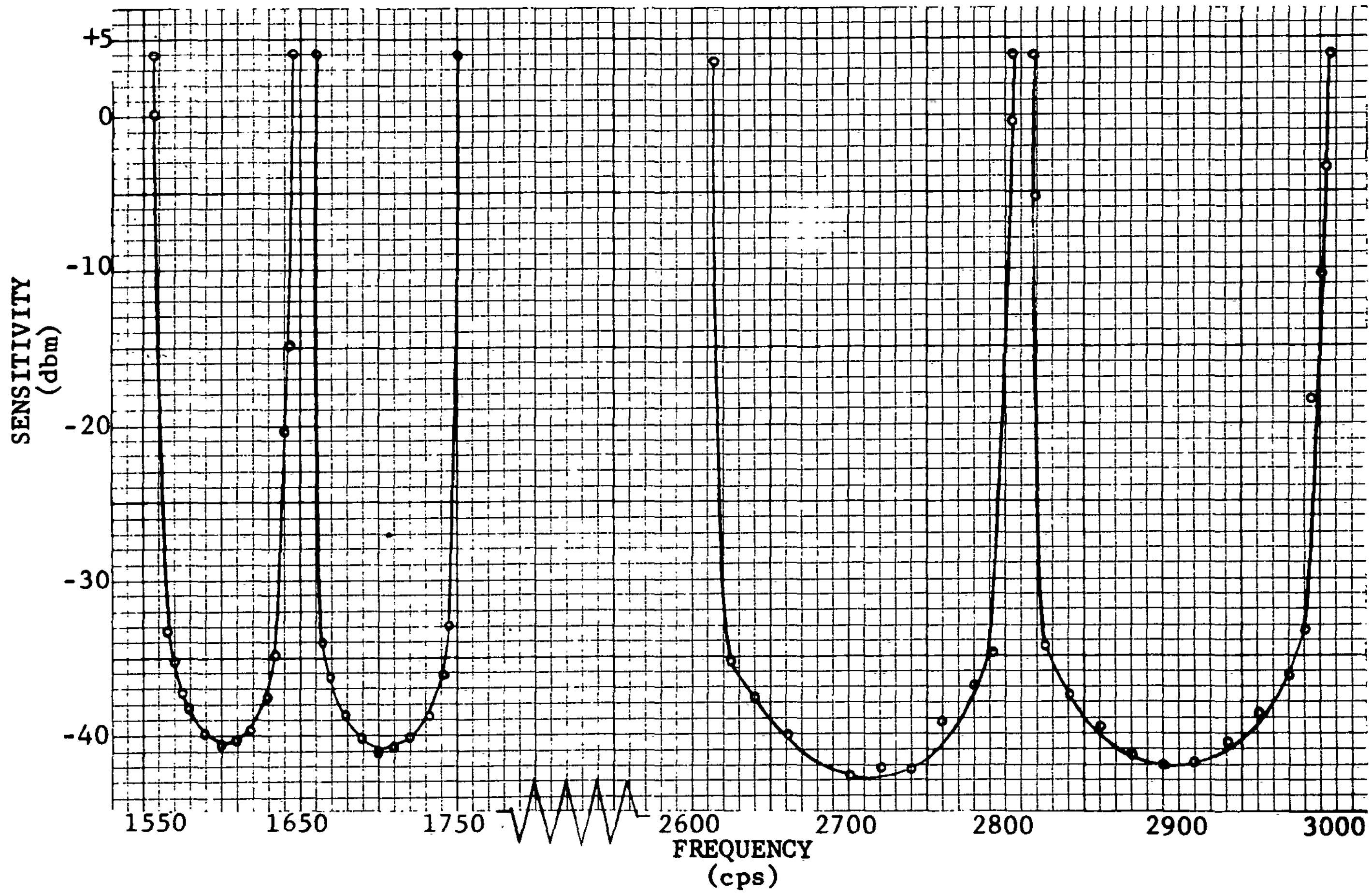


FIGURE B-101

TONE DETECTOR SELECTIVITY CURVES - TA-375/TTC SN 1
Channels Tested 2

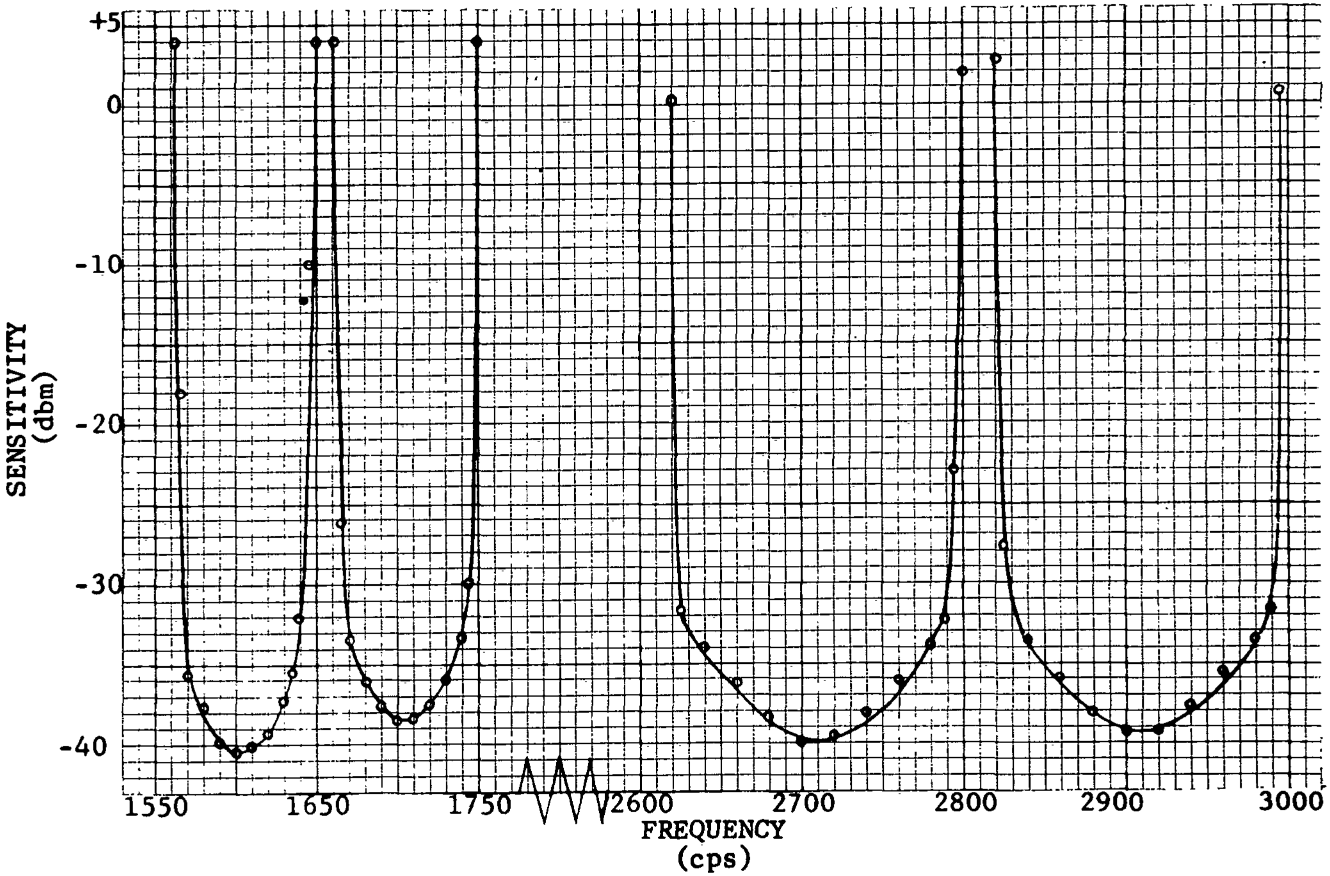


FIGURE B-102

TONE DETECTOR SELECTIVITY CURVES - TA-375/TTC SN 2
Channels Tested 2

2.6 TEST OF TA-376/TTC TELEPHONE SIGNAL CONVERTER

2.6.1 GENERAL DESCRIPTION OF EQUIPMENT

The TA-376 converter is a transportable, lightweight, transistorized, four-channel converter.

2.6.2 OPERATIONAL DESCRIPTION

The TA-376 converter is called the civilian central office converter. It connects civilian central offices and four wire electronic switching centers.

2.6.3 TECHNICAL DESCRIPTION

The TA-376 has the following characteristics:

Circuit Capacity	4 channels
Input power	± 12 volts dc or 115/230 volts ac 50/60 cps
Signalling frequencies	
Transmit	16-24,1600,1700, 1900,2100,2500, 2700,2900 cps
Receive	15-25,1600,1700, 2700,2900 cps
Dial Characteristics	
Speed	10 ± 2 cps
% Make	38.5 ± 2%
% Break	61.5 ∓ 2%

2.6.4 TEST RESULTS - TA-376/TTC TELEPHONE SIGNAL CONVERTER

2.6.4.1 IMPEDANCE (4 WIRE SIDE)

Impedance measurements were made on the 4 wire side of TA-376/TTC SN 1 and SN 2 signal converters in common battery and magneto modes of operation. Plots of the data obtained on 4 channels (averaged) of the Receive pairs are shown in Figures B-103 and B-104. Plots of the data obtained on 4 channels (averaged) of the Transmit pairs are shown in Figures B-105 and B-106.

2.6.4.2 IMPEDANCE (2 WIRE SIDE)

Impedance measurements were made on the 2 wire side of TA-376/TTC SN 1 and SN 2 signal

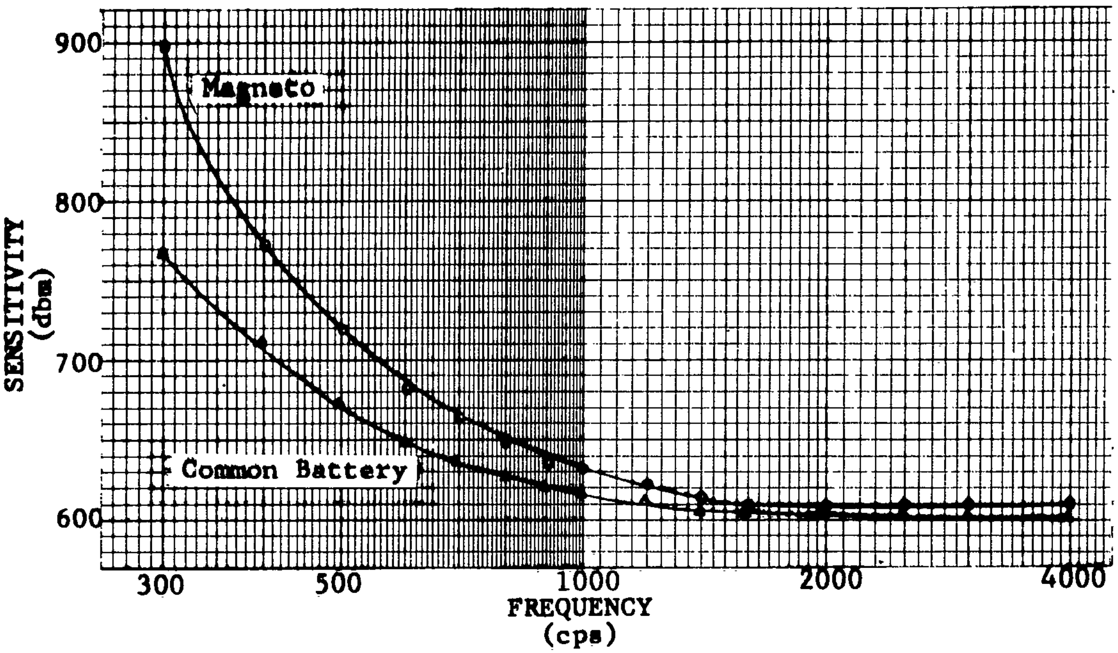


FIGURE B-103

IMPEDANCE (4 WIRE SIDE RECEIVER PAIR) - TA-376/TTC SN 1
Channels Tested 4

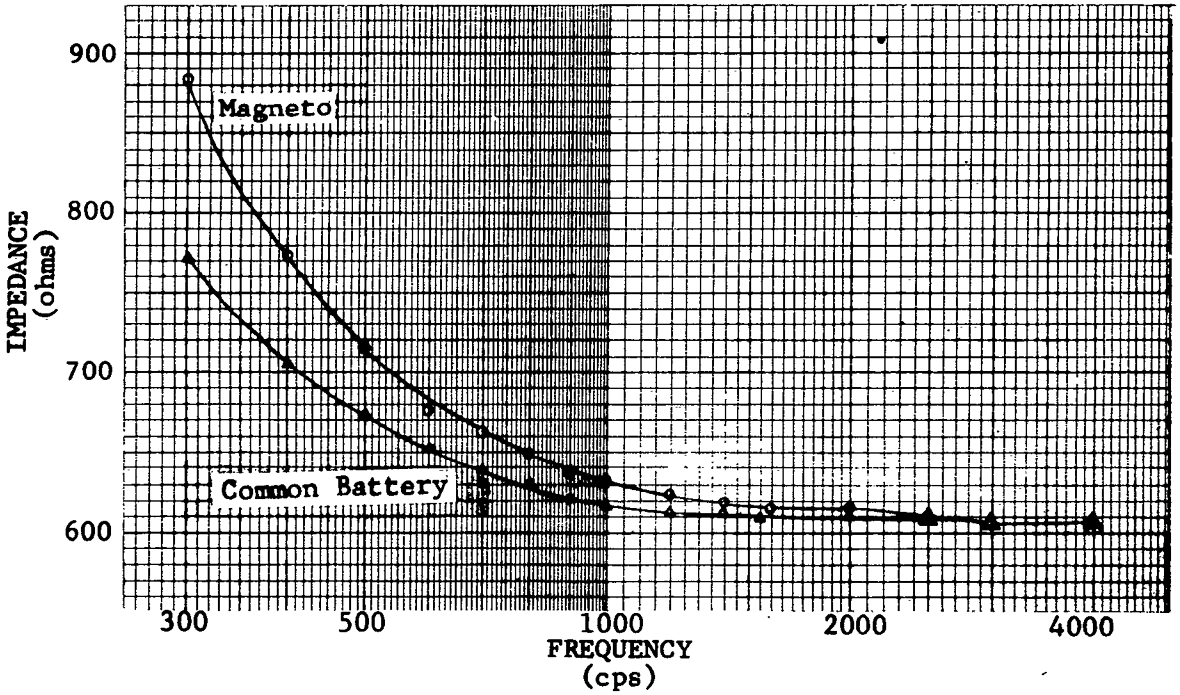


FIGURE B-104

IMPEDANCE (4 WIRE SIDE RECEIVE PAIR) TA-376 SN 2
Channels Tested 4

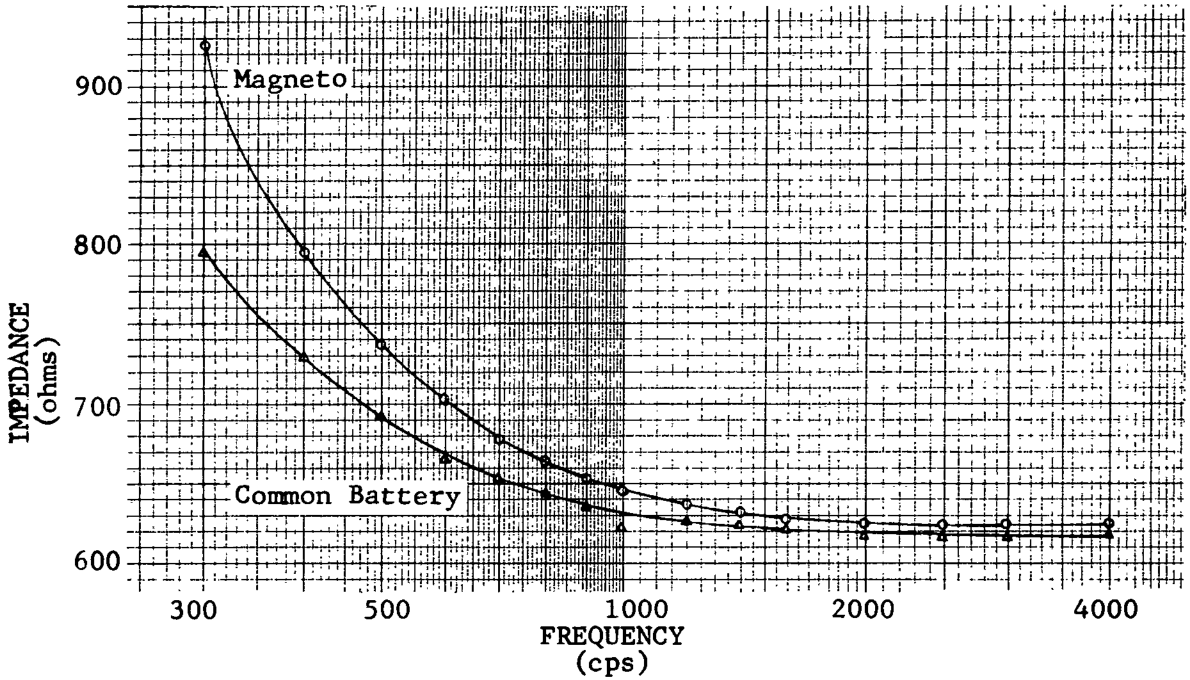


FIGURE B-105

IMPEDANCE (4 WIRE SIDE TRANSMIT PAIR) TA-376/TTC SN 1
Channels Tested 4

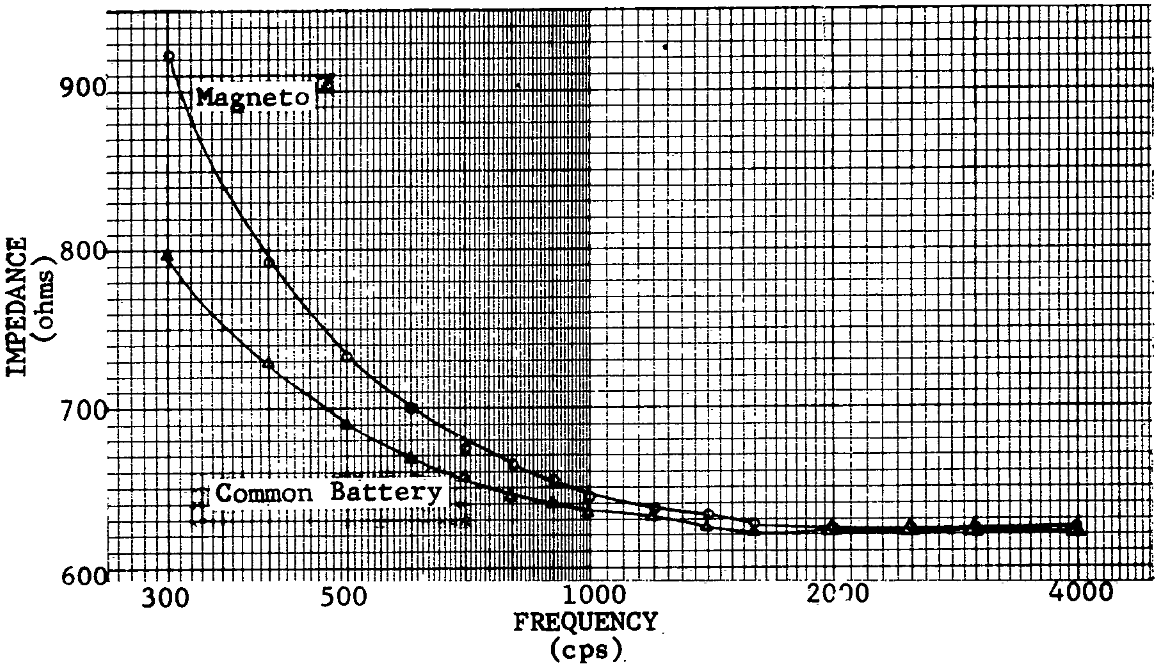


FIGURE B-106

IMPEDANCE (4 WIRE SIDE TRANSMIT PAIR) TA-376/TTC SN 2
Channels Tested 4

converters in common battery and magneto modes of operation. Plots of the data obtained (4 channels averaged) are shown in Figures B-107 and B-108.

2.6.4.3 FREQUENCY RESPONSE

Frequency response measurements were made for four wire in - two wire out and for two wire in - four wire out configurations on the TA-376/TTC SN 1 and SN 2 signal converters. Plots of the data obtained in magneto mode are presented in Figures B-109 through B-112. Frequency response measurements were made in common battery for purposes of comparison. A plot of the data obtained in common battery mode is presented in Figure B-113. It is to be noted that the frequency response below 300 cycles per second is attenuated when the equipment is operated in magneto mode. The insertion loss at 1000 cps approximates -3.5 db.

2.6.4.4 CROSSTALK

The near and far end crosstalk loss was greater than 92 db below the referenced signal level (below the range of power measurable with test equipment) in either magneto or battery modes for two wire in - four wire out, and four wire in - two wire out on the TA-376/TTC SN 1 and SN 2 signal converters.

2.6.4.5 HARMONIC DISTORTION

The harmonic distortion, produced in the TA-376/TTC SN 1 and SN 2 signal converters, was within the instrumental error of the testing equipment and was, therefore, lower than 0.2 per cent.

2.6.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on the TA-376/TTC SN 1 and SN 2 signal converters. A pair of fundamental frequencies (f_1 and f_2) separated by 200 cps and producing a total input signal level of -4 dbm were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$), cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$), and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $2f_1 + 2f_2$) distortion products falling within the equipment passband were measured for each frequency pair and are shown in Figures B-114 and B-115. All distortion products were found to be more than 46 db down from the individual fundamentals.

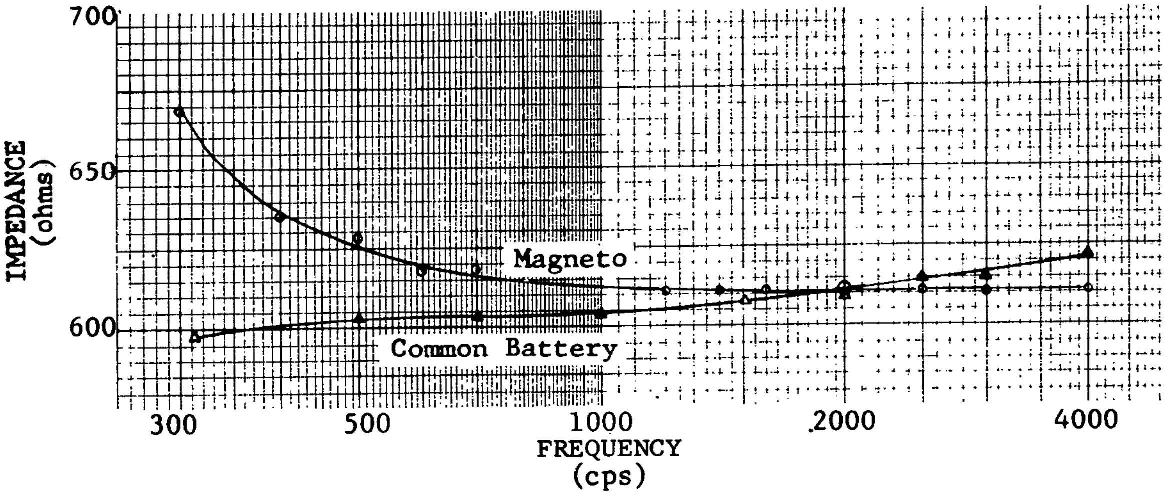


FIGURE B-107

IMPEDANCE (2 WIRE SIDE) - TA-376/TTC SN 1
Channels Tested 4

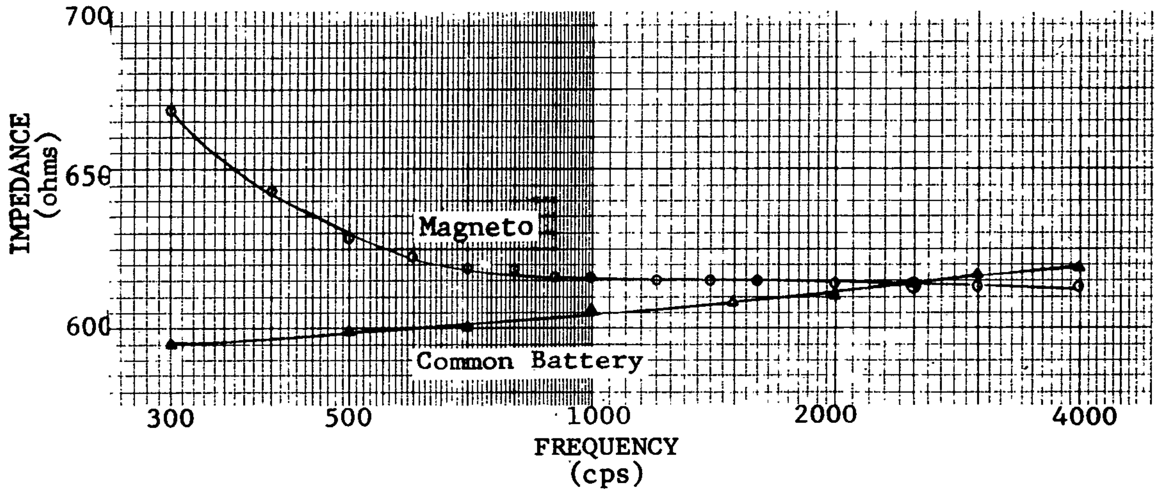


FIGURE B-108

IMPEDANCE (2 WIRE SIDE) TA-376/TTC SN 2
Channels Tested 4

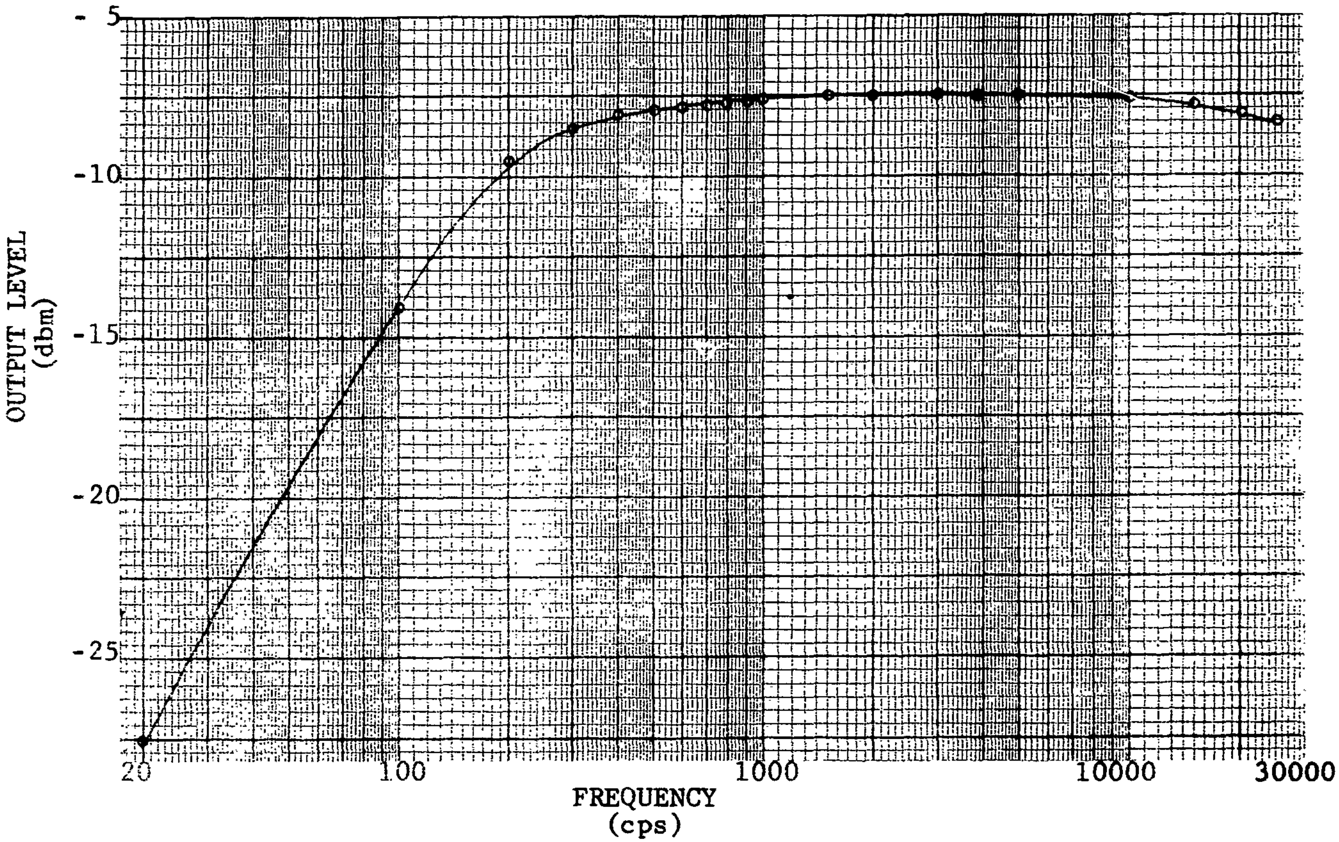


FIGURE B-109

FREQUENCY RESPONSE - TA-376/TTC SN 1
Magneto Mode - 4 Wire In - 2 Wire Out
Input Level -4 dbm

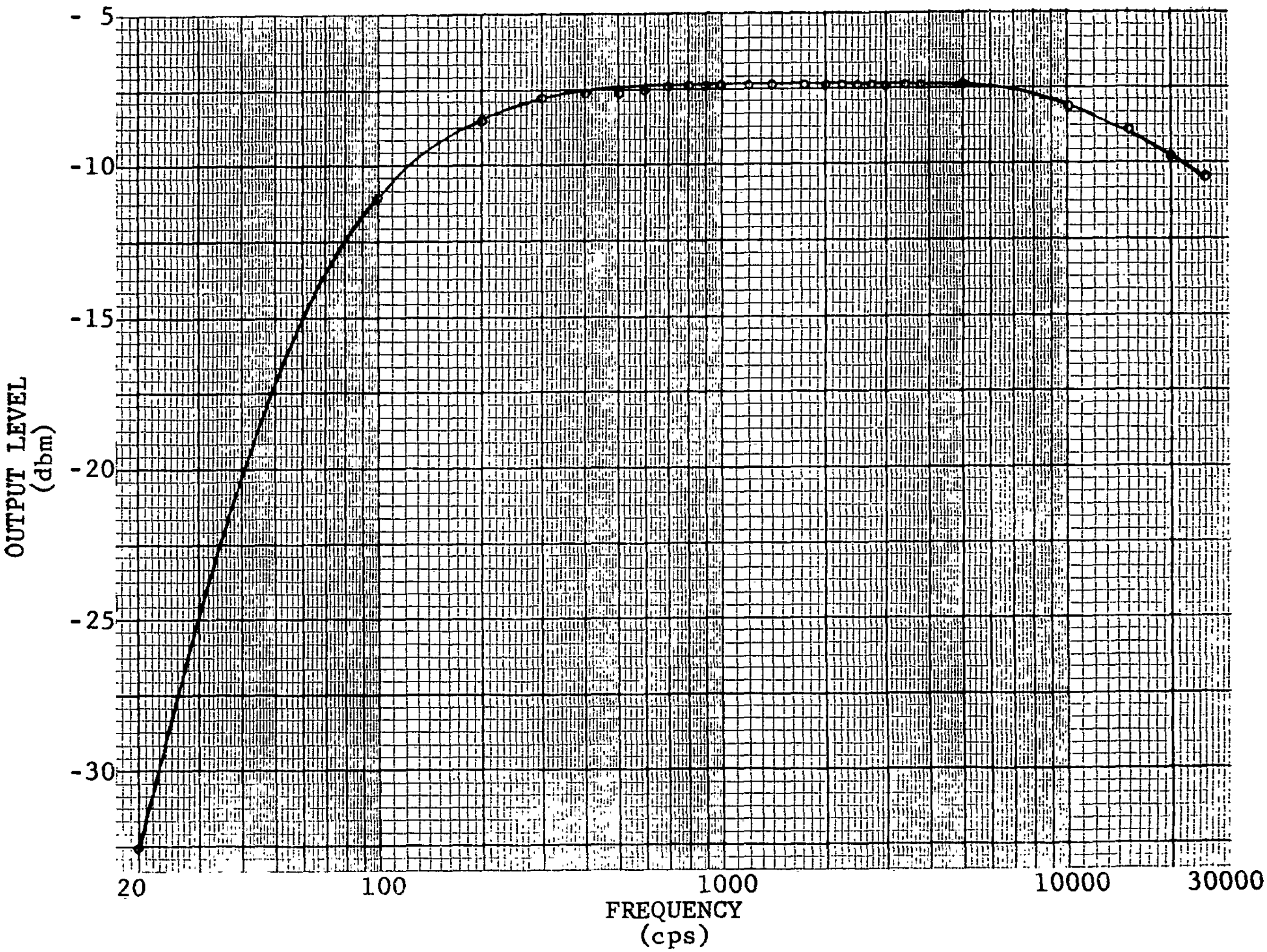


FIGURE B-110

FREQUENCY RESPONSE - TA-376/TTC SN 1
Magneto Mode - 2 Wire In - 4 Wire Out
Input Level -4 dbm

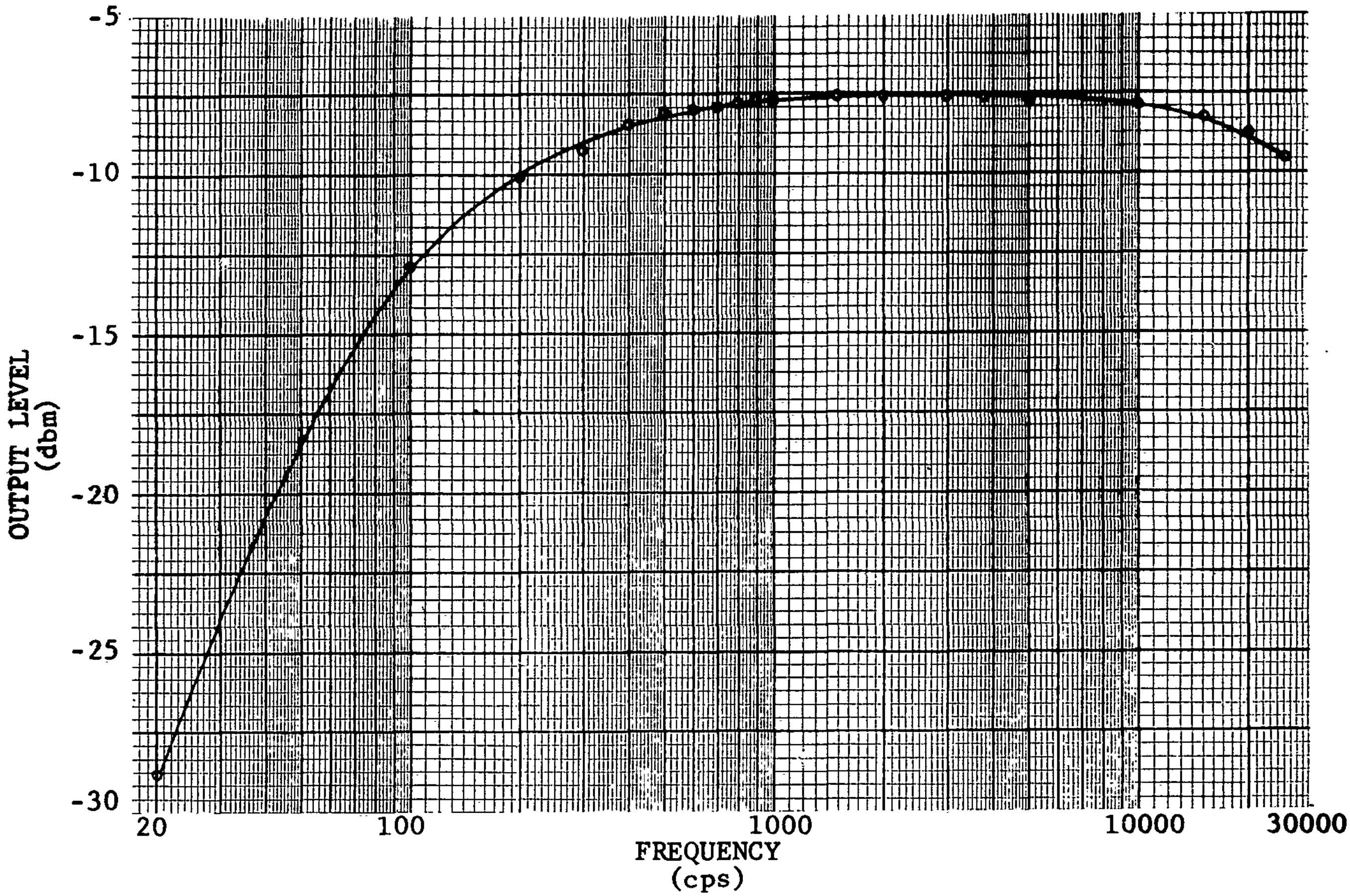


FIGURE B-111

FREQUENCY RESPONSE TA-376/TTC SN 2
Magneto Mode - 4 Wire In - 2 Wire Out
Input Level -4 dbm

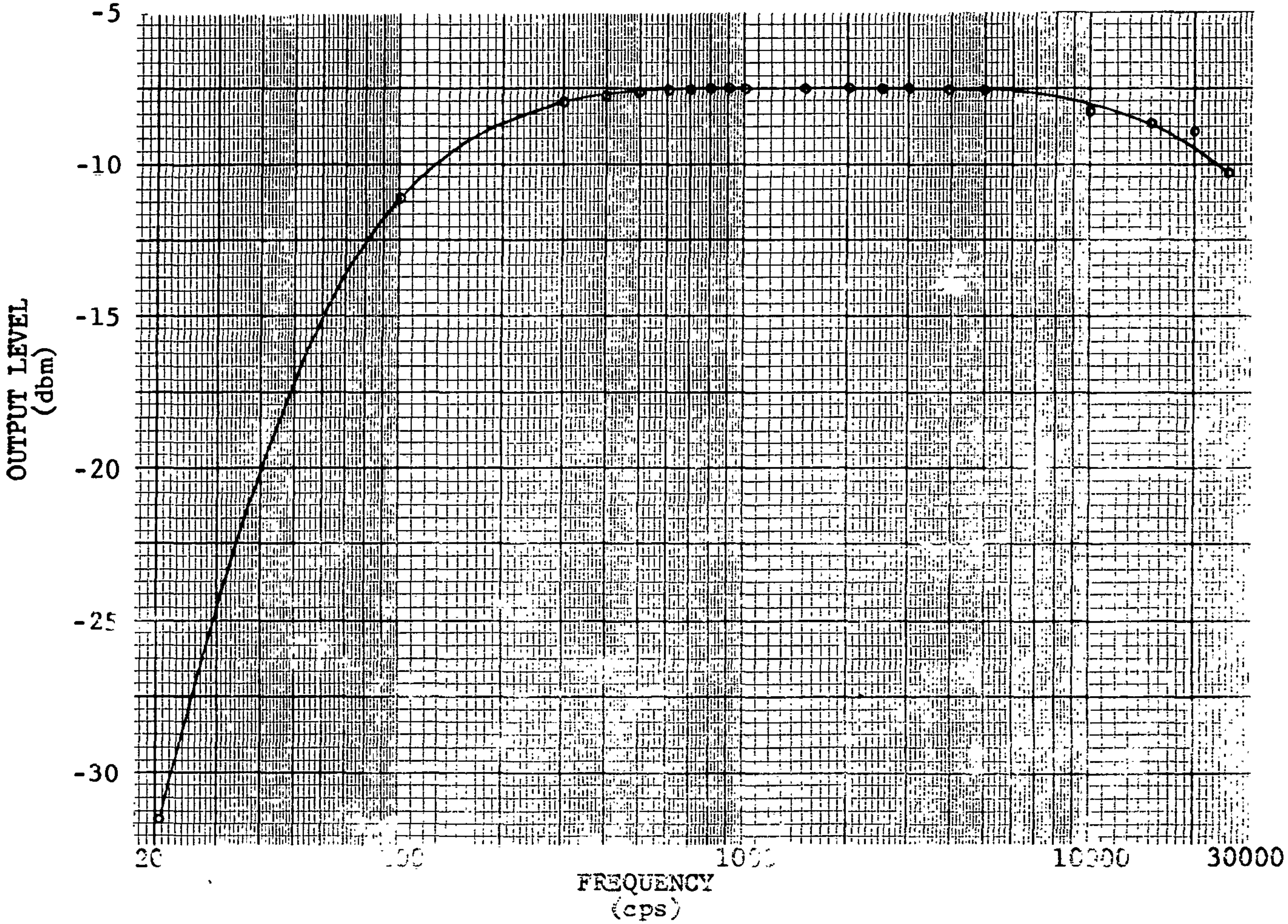


FIGURE B-112

FREQUENCY RESPONSE TA-376/TTC SN 2
Magneto Mode - 2 Wire In - 4 Wire Out
Input Level -4 dbm

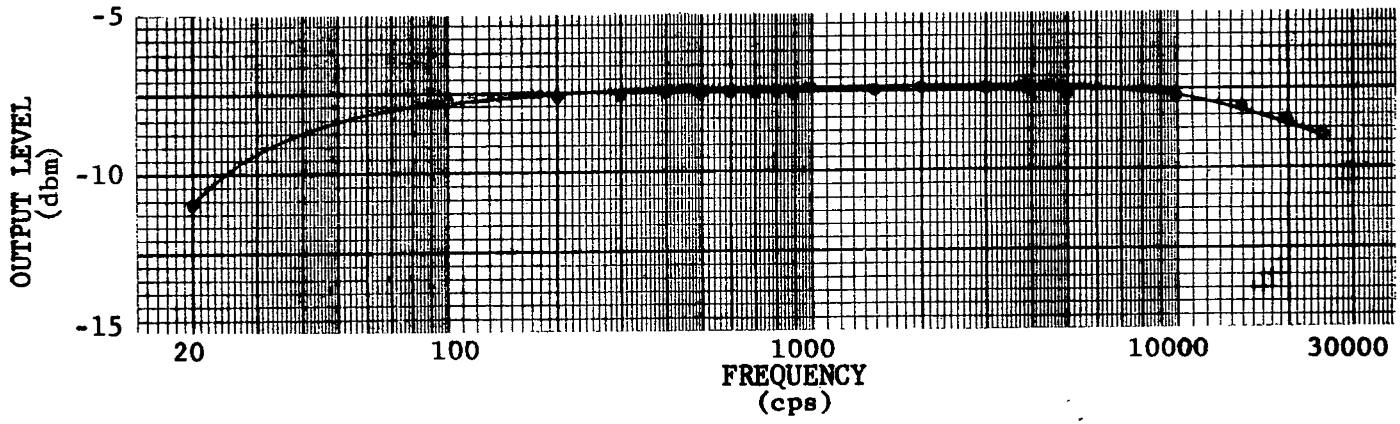


FIGURE B-113

FREQUENCY RESPONSE TA-376/TTC SN 1
Common Battery Mode - 2 Wire In - 4 Wire Out
Input Level -4 dbm

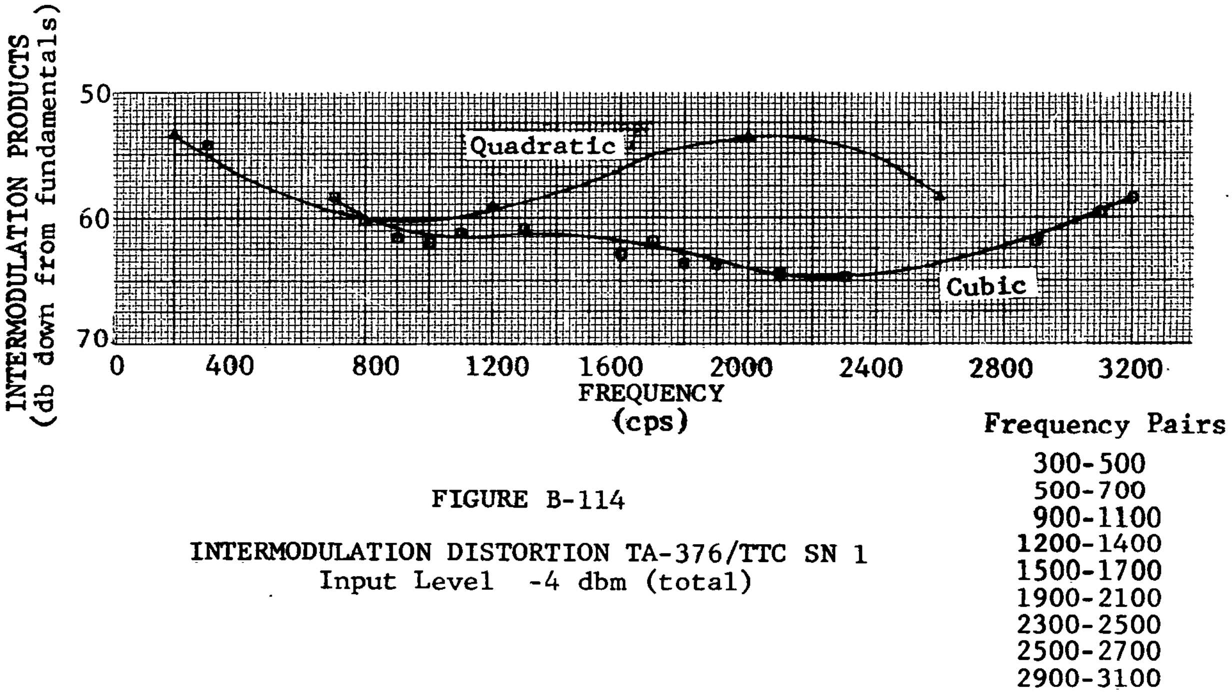


FIGURE B-114

INTERMODULATION DISTORTION TA-376/TTC SN 1
Input Level -4 dbm (total)

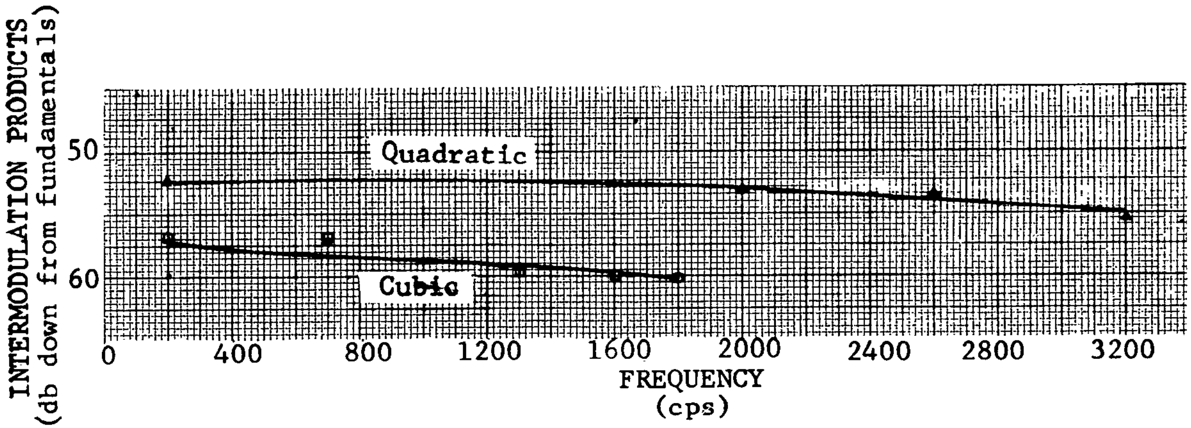


FIGURE B-115

INTERMODULATION DISTORTION
TA-376/TTC SN 2
Input Level -4 dbm (total)

2.6.4.7 NOISE

Noise measurements taken on all channels of the TA-376/TTC SN 1 and SN 2 showed noise levels to be below 17 dba (-68 dbm) the sensitivity of the instrumentation.

2.6.4.8 PHASE DISTORTION

Envelope delay distortion measurements were made on the TA-376/TTC SN 1 and SN 2 signal converters. Maximum distortion occurs between 300 and 1000 cps. The distortion decreased from 70 microseconds at 300 cps to approximately 10 microseconds at 1000 cps. The distortion present in the frequency range used for signalling in the electronic switchboards (1600 to 2900 cps) was in the order of 10 microseconds. Accurate data could not be obtained due to the limitations of the instrumentation (55 microseconds) at the low delays experienced.

2.6.4.9 LONGITUDINAL BALANCE

Longitudinal balance measurements were taken between all channels and ground for 2 wire in - 4 wire out and for 4 wire in - 2 wire out connections on the TA-376/TTC SN 1 and SN 2 signal converters. All measurements showed the longitudinal balance to be more than 78 db below the referenced signal level (the limit of the instrumentation).

2.6.4.10 LIMITING

Limiting was measured on channels of the TA-376/TTC SN 1 and SN 2 signal converters. No limiting action was noted over the range of input signal levels used (-12 to +12 dbm). Plots of the output level (dbm) versus input level (dbm) are shown in Figures B-116 and B-117.

2.6.4.11 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits of the TA-376/TTC SN 1 and SN 2 signal converters. Figures B-118 through B-121 show plots of the data obtained. The sensitivity and selectivity for common battery mode is the same as for magneto mode with the exception of the 20 cps ring detector.

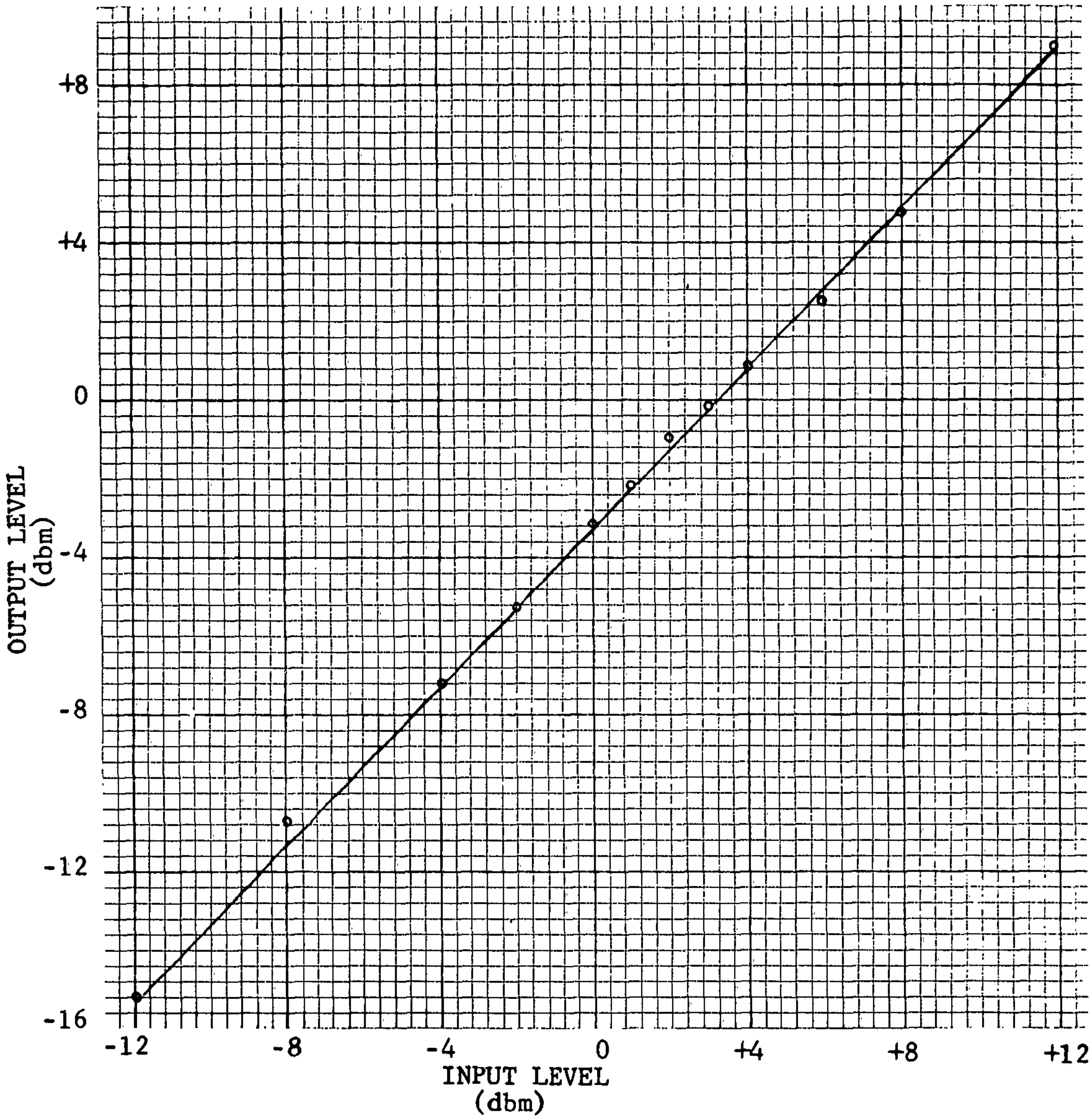


FIGURE B-116

LIMITING - TA-376/TTC SN 1
(Magneto Mode)
Channels Tested 4

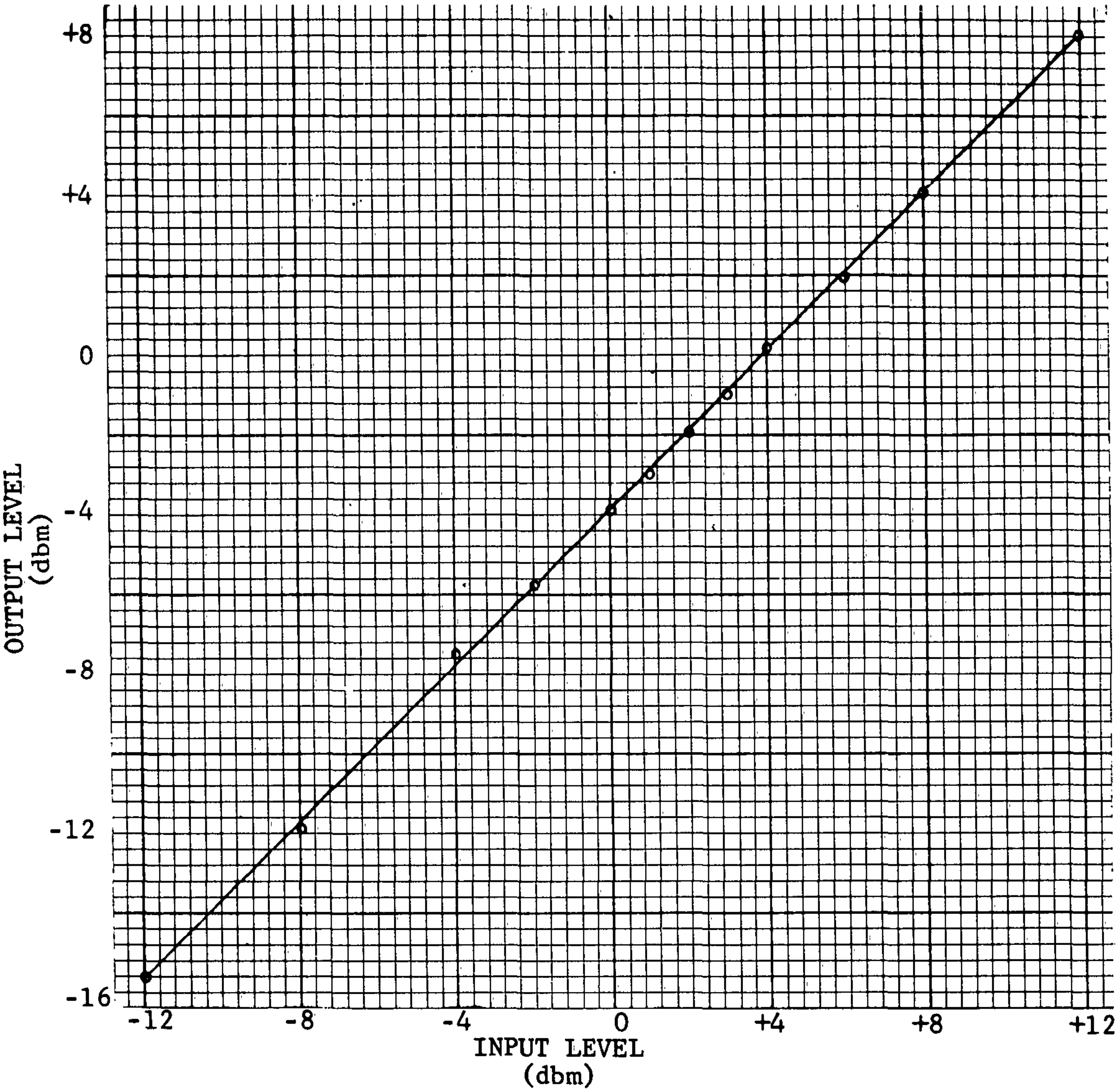


FIGURE B-117

LIMITING - TA-376/TTC SN 2
(Magneto Mode)
Channels Tested 2

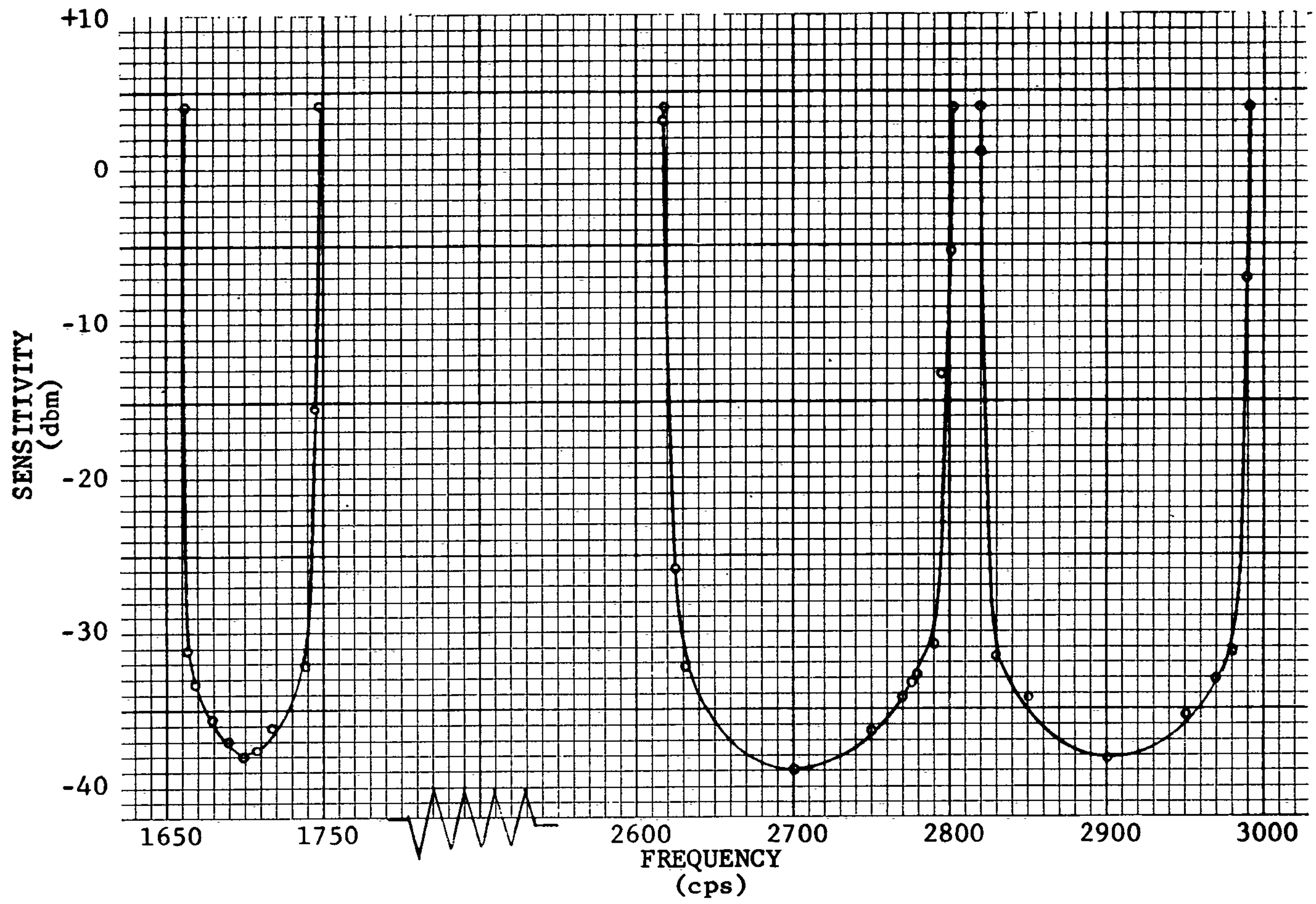


FIGURE B-118

TONE DETECTOR SELECTIVITY CURVES - TA-376/TTC SN 1
Channels Tested 4

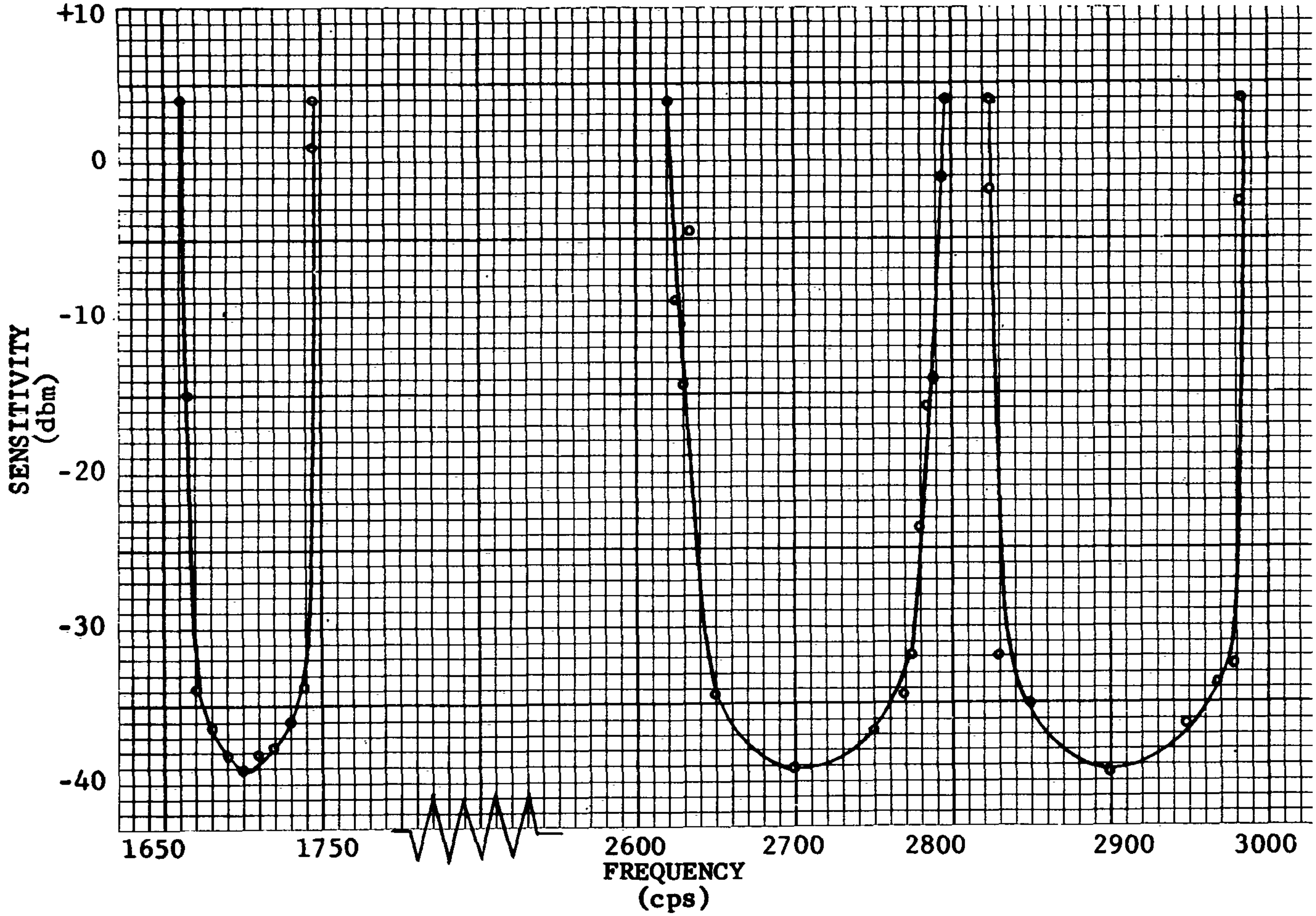


FIGURE B-119

TONE DETECTOR SELECTIVITY CURVES - TA-376/TTC SN 2
Channels Tested 2

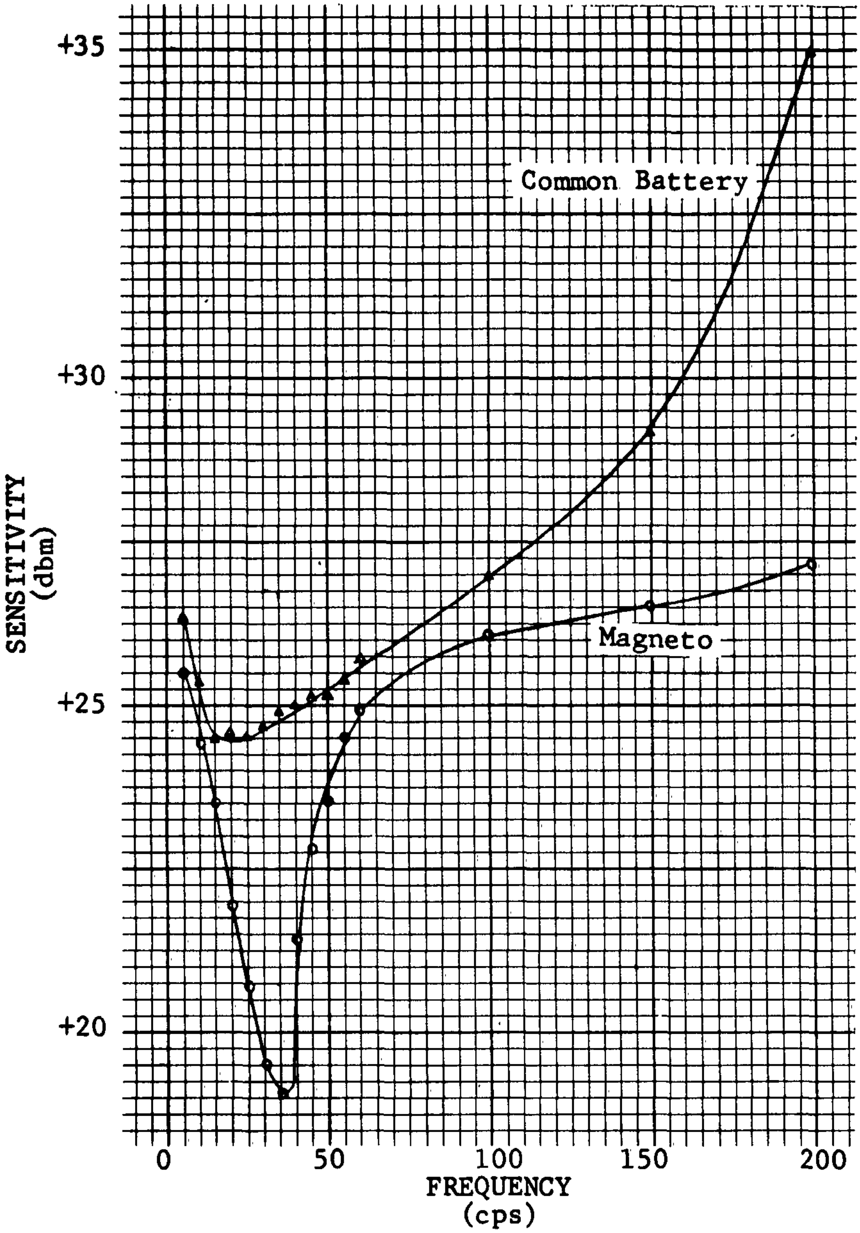


FIGURE B-120

20 CPS RING DETECTOR SELECTIVITY CURVES
TA-376/TTC SN 1
Common Battery and Magneto Mode
Channels Tested 2

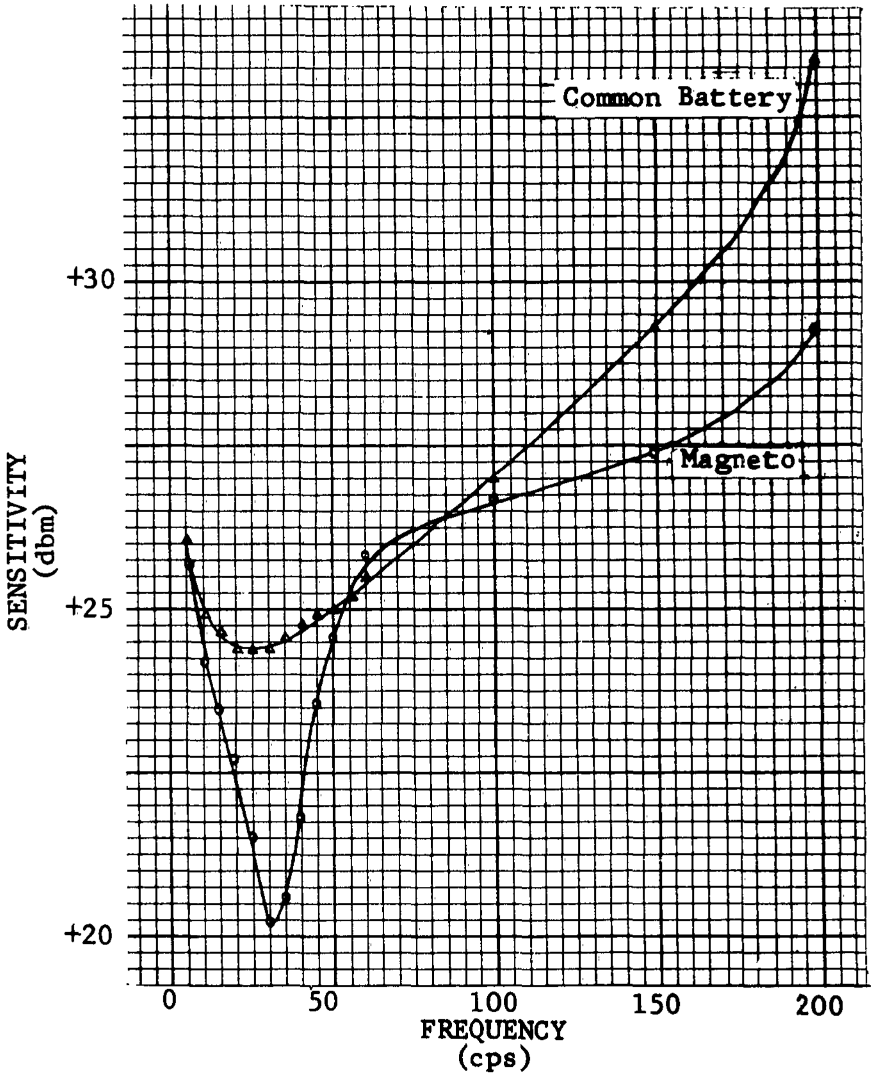


FIGURE B-121

20 CPS RING DETECTOR SELECTIVITY CURVE
TA-376/TTC SN 2
Common Battery and Magneto Mode
Channels Tested 2

2.6.4.12 TONE GENERATOR OUTPUT

The frequency and power output of the several tone generators of the TA-376/TTC SN 1 and SN 2 were measured. The data obtained are tabulated in Tables B-52 and B-53.

2.6.4.13 TRANSHYBRID LOSS

Transhybrid loss measurements were made on the TA-376/TTC SN 1 and SN 2 signal converters. The data obtained is tabulated in Table B-54.

2.7 TEST OF TA-344/G FIELD WIRE REPEATER

2.7.1 GENERAL DESCRIPTION OF EQUIPMENT

The TA-344/G Field wire repeater is a portable, lightweight (5-10 pounds), transistorized, two channel line amplifier.

2.7.2 OPERATIONAL DESCRIPTION

The TA-344/G field wire repeater is designed to extend the usable length of WF-16 four conductor field wire. Each channel has one amplifier which is normally used in the send pair of a four wire circuit. The receive pair is normally patched straight through. The amplifiers are one way devices, however, the direction may be reversed by a switch in one of the two channels. Power is supplied by two self contained batteries. The amplifier units are interchangeable with the AM-2261/TT Amplifier Assembly.

2.7.3 TECHNICAL DESCRIPTION

Circuit Capacity	2 channels
Power	Two Batteries - Internal
Amplifiers	Transistorized plug-in sub-assemblies
Connections	Binding posts

TABLE B-52

TONE GENERATOR OUTPUT - TA-376/TTC SN 1

TONE GENERATOR	FREQUENCY (cps)	OUTPUT LEVEL (dbm)
Seize - S	1702	-18.2
"O" Digit - U	1904	-17.0
X	2510	-17.0
Release - Y	2707	-17.3
Z	2906	-17.2
Interlock - V	2100 *	-17.4
Z	2900 *	-17.4

* 100 millisecond burst of VZ tones prevented the exact reading of the frequency with the counter

TABLE B-53

TONE GENERATOR OUTPUT - TA-376/TTC SN 2

TONE GENERATOR	FREQUENCY (cps)	OUTPUT LEVEL (dbm)
Seize - S	1705	-17.9
"O" Digit - U	1905	-17.5
X	2506	-16.5
Release - Y	2705	-18.0
Z	2906	-17.0
Interlock - V	2100 *	-17.3
Z	2900 *	-16.5

* 100 millisecond burst of VZ tones prevented the exact reading of the frequency with the counter

TABLE B-54

TRANSHYBRID LOSS - TA-376/TTC SN 1 AND SN 2
Input Signal Level -4 dbm
Channels Tested 3

SN 1		SN 1		SN 2	
Measurement at 4 Wire Side (dbm) (1000 cps in 2 wire side)		Measurement at 4 Wire Side (dbm) (1000 cps in 4 wire side)		Measurement at 4 Wire Side (dbm) (1000 cps in 4 wire side)	
Common Battery	Magneto	Common Battery	Magneto	Common Battery	Magneto
-7.3	-7.3	-25.2	-29.0	-24.5	-28.0
-7.4	-7.4	-24.5	-27.8	-24.8	-28.5
-7.4	-7.4	-24.5	-28.0	-25.2	-29.0

2.7.4 TEST RESULTS TA-344/G FIELD WIRE

2.7.4.1 INPUT IMPEDANCE

Input impedance measurements were made on all channels of the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters. The impedance was found to be nominally 600 ohms ± 2 per cent. Plots of the impedance versus frequency are shown in Figures B-122 through B-124.

2.7.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on all channels of the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters. The impedance ranged from 325 ohms at 300 cps to a maximum of 638 ohms at 1300 cps. Plots of the impedance versus frequency are shown in Figures B-125 through B-127.

2.7.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on all channels of the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters. Plots of the frequency response are shown in Figures B-128 through B-130. The input signal level used was -18 dbm. The gain at 1000 cps in the repeaters was 11.6, 11.8, and 11.8 db for the SN 1, SN 2 and SN 3 respectively.

2.7.4.4 CROSSTALK LOSS

Measurements were made of near end and far end crosstalk loss on both channels of the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters. The near end crosstalk loss exceeds 69 db down from the disturbing signal level. The data obtained is tabulated in Tables B-55 and B-56.

2.7.4.5 HARMONIC DISTORTION

The harmonic distortion produced in the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters was found to be less than the 0.2 per cent instrumental accuracy of the testing equipment.

2.7.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured using a combined input signal level of -18 dbm on the TA-344/G field wire repeaters SN 1, SN 2 and SN 3. A pair of fundamental frequencies (f_1 and f_2)

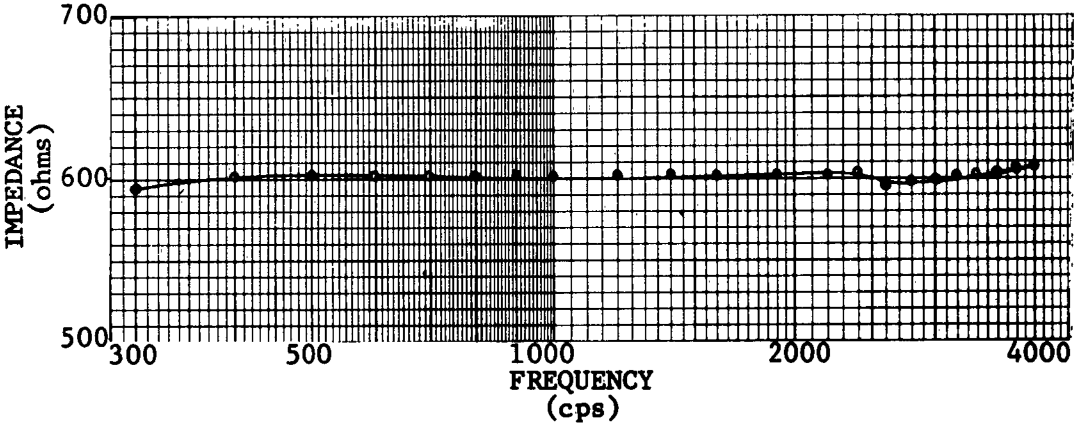


FIGURE B-122

INPUT IMPEDANCE - TA-344/G SN 1
Channels Tested 2

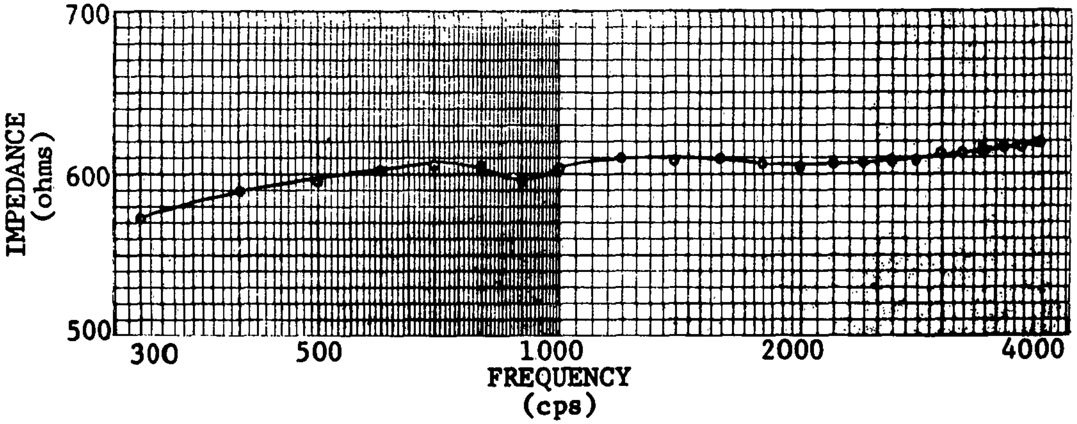


FIGURE B-123

INPUT IMPEDANCE - TA-344/G SN 2
Channels Tested 2

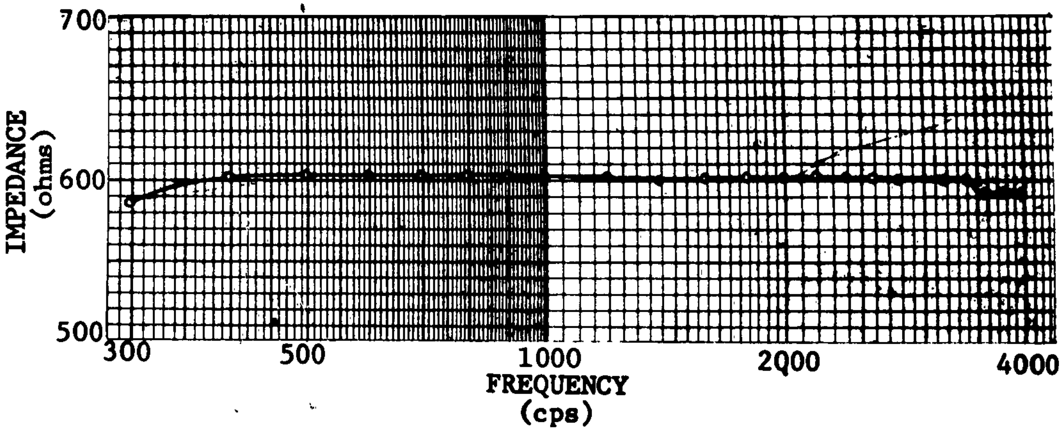


FIGURE B-124

INPUT IMPEDANCE - TA-344/G SN 3
Channels Tested 2

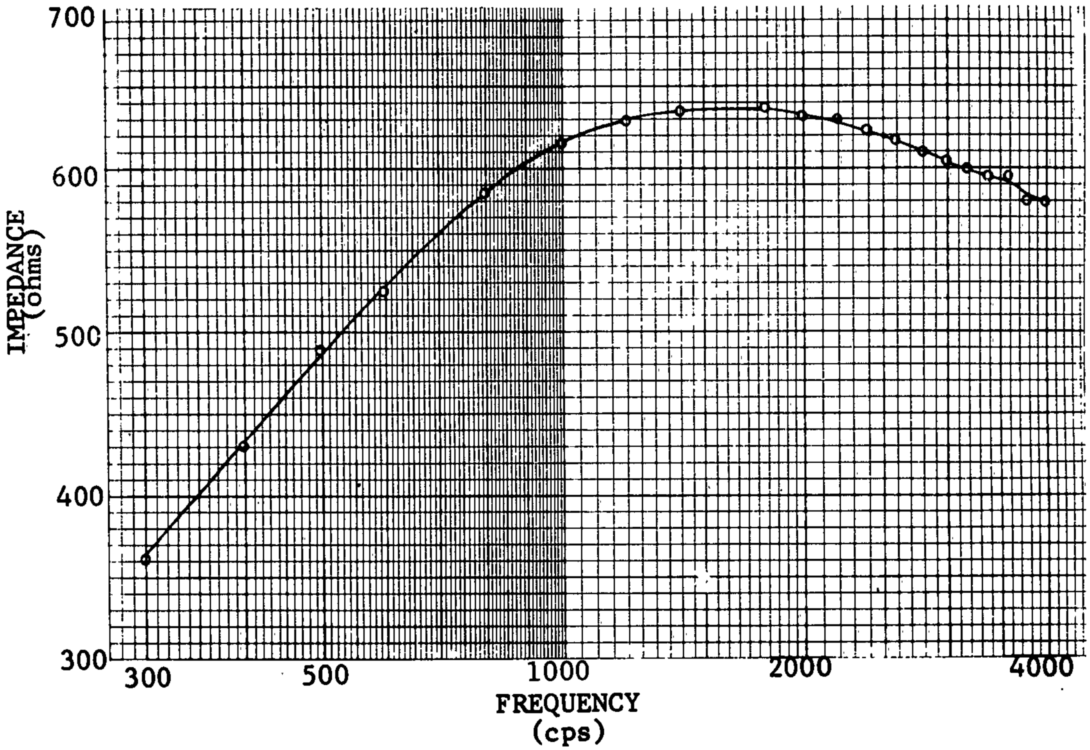


FIGURE B-125

OUTPUT IMPEDANCE - TA-344/G SN 1
Channels Tested 2

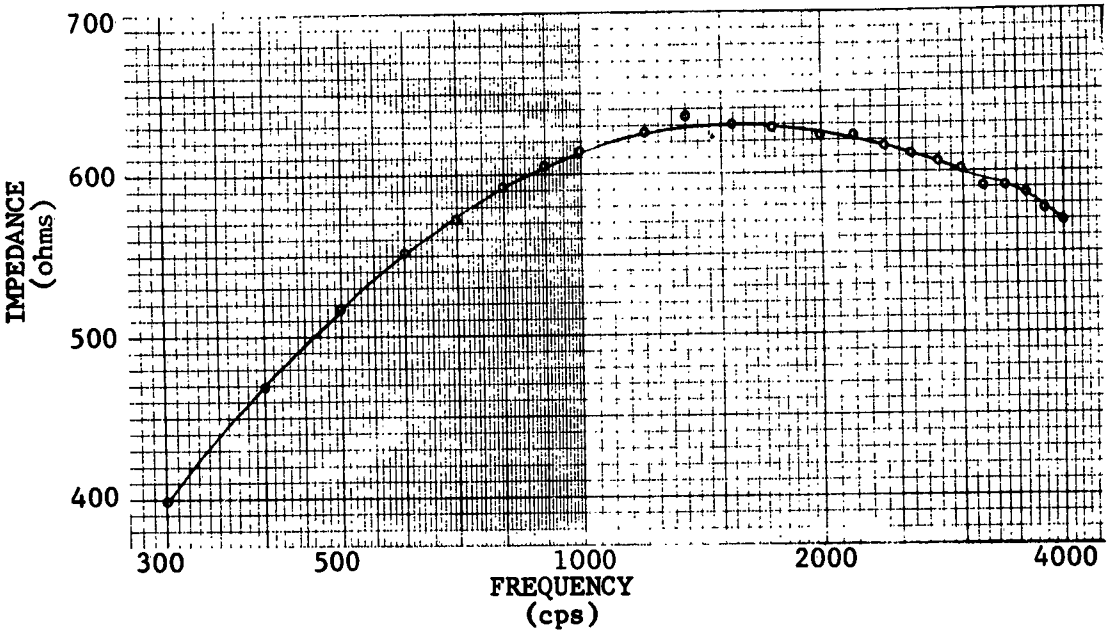


FIGURE B-126

OUTPUT IMPEDANCE - TA-344/G SN 2
Channels Tested 2

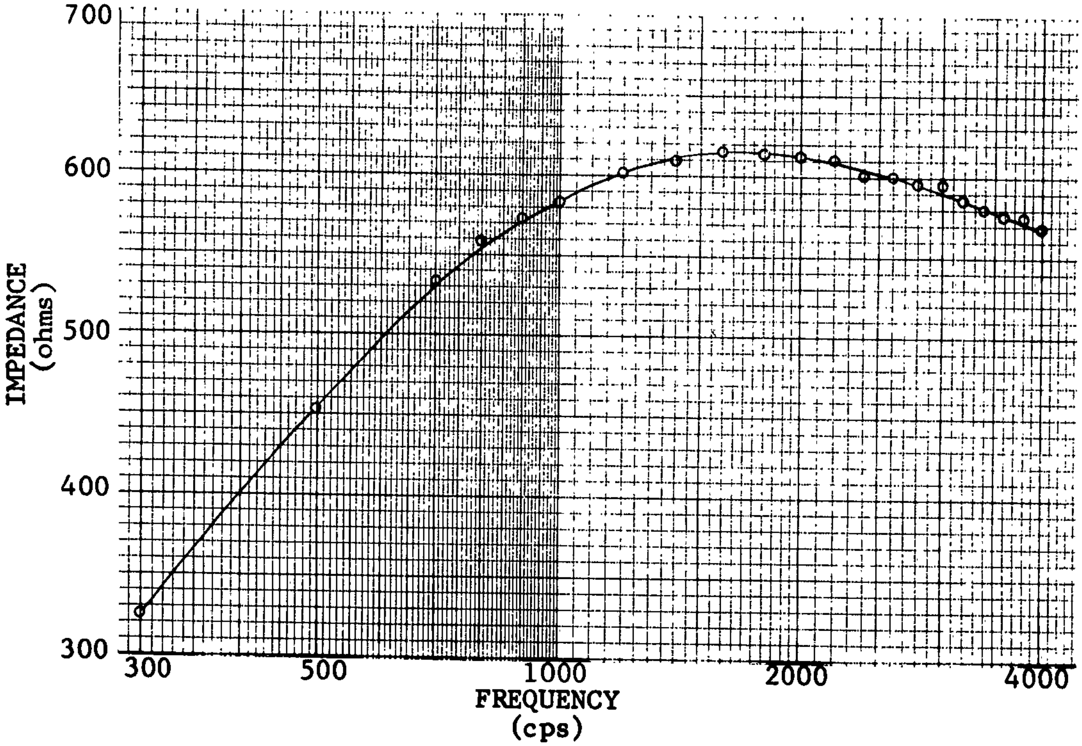


FIGURE B-127

OUTPUT IMPEDANCE - TA-344/G SN 3
Channels Tested 2

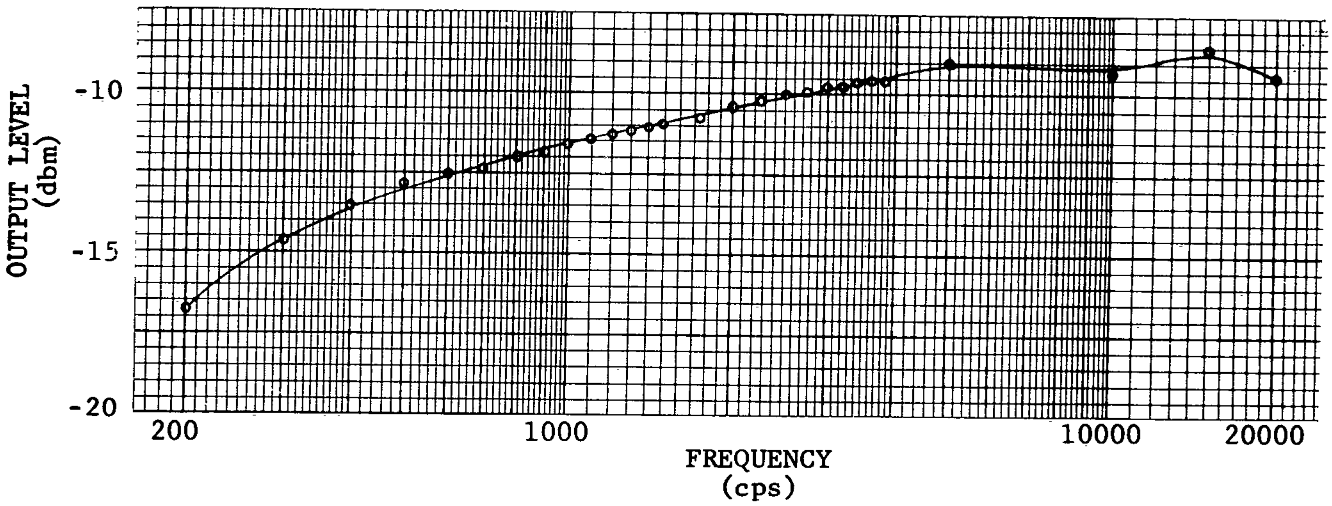


FIGURE B-128

FREQUENCY RESPONSE - TA-344/G SN 1
Input Signal Level -18 dbm

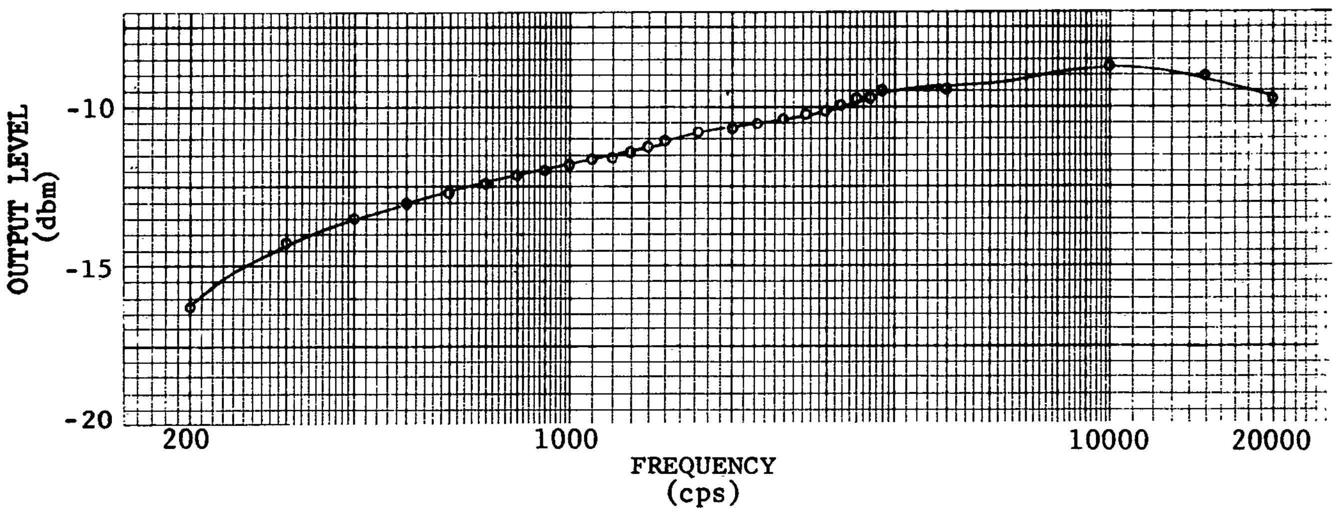


FIGURE B-129

FREQUENCY RESPONSE - TA-344/G SN 2
Input Signal Level -18 dbm

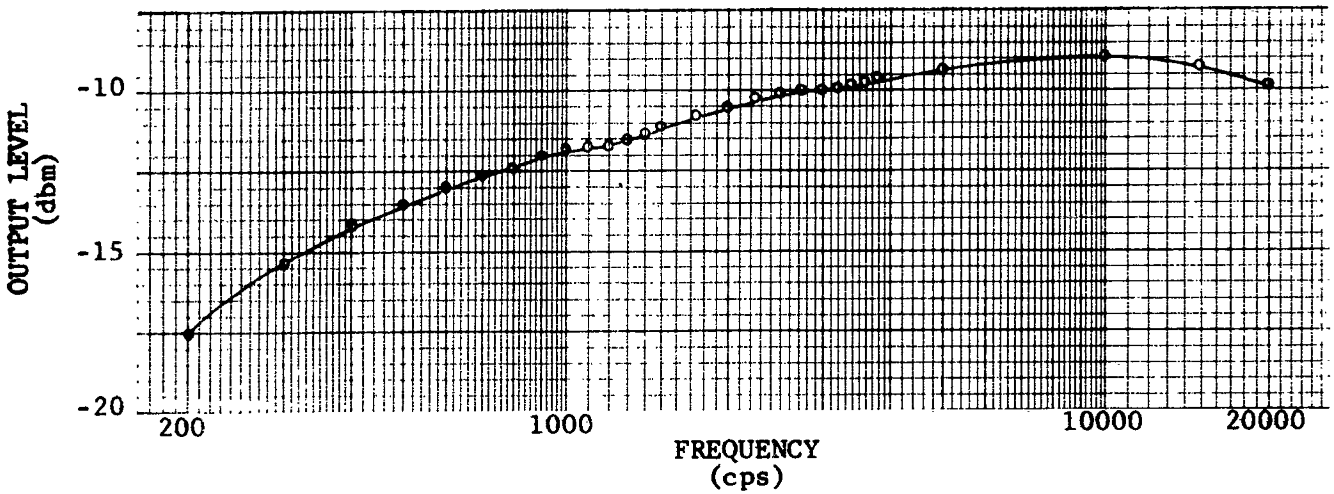


FIGURE B-130

FREQUENCY RESPONSE - TA-344/G SN 3
Input Signal Level -18 dbm

TABLE B-55

NEAR END CROSSTALK LOSS TA-344/G
SN 1, SN 2 AND SN 3
Input Signal Level -18 dbm
Decibels Down From Reference Signal Level

FREQUENCY (cps)	SN 1 Channel 1	SN 1 Channel 2	SN 2 Channel 1	SN 2 Channel 2	SN 3 Channel 1	SN 3 Channel 2
300	69.6	73.4	71.0	71.9	71.2	72.0
600	69.8	73.4	71.0	71.9	71.2	72.0
1000	69.8	73.3	71.0	71.9	71.1	72.0
1200	69.8	73.2	71.0	71.9	71.0	72.0
1500	69.8	73.2	71.0	71.9	71.0	72.0
1700	69.8	73.2	71.0	71.8	71.0	72.0
1900	69.8	73.1	71.0	71.9	69.9	72.0
2100	69.8	73.1	71.0	71.9	69.8	72.0
2300	69.8	73.1	71.0	71.9	69.8	72.0
2500	69.8	73.1	71.0	71.9	69.8	72.0
2700	69.8	73.0	71.0	71.9	69.8	72.0
2900	69.8	73.0	71.0	71.9	69.7	72.0
3100	69.4	73.0	71.0	71.9	69.7	72.0
3300	69.4	73.0	71.0	71.9	69.7	72.0
3500	69.4	73.0	71.0	71.9	69.7	71.9
4000	69.5	73.0	71.0	71.9	69.2	71.9
5000	69.3	73.0	71.0	71.9	69.2	71.9
6000	69.4	73.0	71.0	71.9	69.2	71.9
Average	69.6	73.1	71.0	71.9	70.2	72.0

TABLE B-56

FAR END CROSSTALK LOSS TA-344/G
SN 1, SN 2 AND SN 3
Input Signal Level -18 dbm
Decibels Down From Reference Signal Level

FREQUENCY (cps)	SN 1		SN 1		SN 1	
	Channel 1	Channel 2	Channel 1	Channel 2	Channel 1	Channel 2
300	63.3	64.8	65.4	65.9	66.0	67.1
600	66.7	67.5	68.1	67.8	68.9	68.9
1000	67.8	68.1	68.6	69.2	70.7	69.6
1200	68.2	68.2	69.0	69.3	70.7	69.8
1500	68.6	68.1	69.1	69.4	70.2	70.0
1700	68.7	68.3	69.2	69.3	71.1	70.0
1900	69.0	68.2	69.4	69.9	71.3	70.0
2100	69.0	68.2	69.5	70.1	71.5	70.1
2300	69.3	68.3	69.6	70.3	71.5	70.2
2500	69.3	68.3	69.7	70.5	71.6	70.4
2700	70.0	68.4	69.8	70.6	71.7	70.4
2900	69.3	68.4	70.0	70.7	71.7	70.5
3100	69.4	68.6	70.2	70.8	71.9	70.7
3300	69.6	68.7	70.3	70.9	72.0	70.8
3500	69.7	68.9	70.4	71.0	72.1	71.0
4000	70.0	69.1	71.0	71.5	72.2	71.5
5000	70.6	70.6	72.0	72.4	73.1	72.3
6000	71.4	71.7	72.9	73.0	74.1	73.4
Average	68.8	68.4	69.6	70.1	71.2	70.3

separated by 200 cps was used. The quadratic (f_2 $-f_1$; f_2 $+f_1$), cubic ($2f_2$ $+f_1$; $2f_2$ $-f_1$; $2f_1$ $+f_2$; $2f_1$ $-f_2$), and quartic ($3f_1$ $-f_2$; $3f_2$ $-f_1$; $3f_1$ $+f_2$; $2f_1$ $+2f_2$; $3f_2$ $+f_1$) distortion products falling within the equipment passband were measured for each frequency pair as shown in Figures B-131 through B-133. The distortion products are seen to be greater than 41 db down from the fundamentals.

2.7.4.7 NOISE

Noise measurements taken on all channels of the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters showed the levels to be below 17 dba (-68 dbm), the sensitivity of the instrumentation.

2.7.4.8 PHASE DISTORTION

The envelope delay time in microseconds was measured on channels of the TA-344/G SN 1, SN 2 and SN 3 using the Phazor Type 200-AB phase-meter (accuracy 1.0 degrees). The delay time decreased from 270 microseconds at 300 cps to approximately 30 microseconds at 1000 cps. The delay time present in the frequency range used for signalling in the electronic switchboards was in the order of 30 microseconds. Accurate data could not be obtained due to the 55 microseconds limitations of the instrumentation.

2.7.4.9 LONGITUDINAL BALANCE

The longitudinal balance between channels of the TA-344/G SN 1, SN 2 and SN 3 were measured. The longitudinal balance was found to be more than 78 db below the referenced input signal level (the limit of the instrumentation).

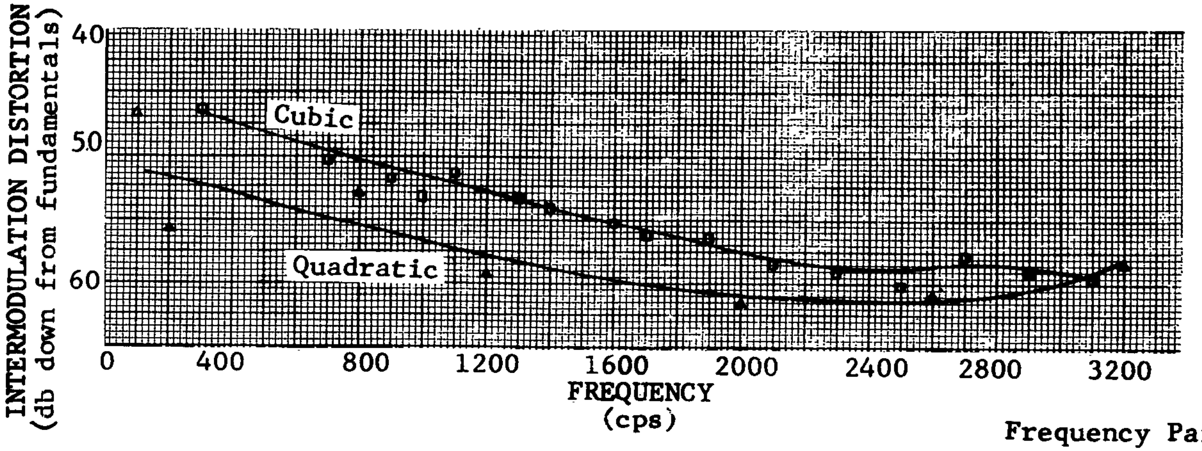
2.7.4.10 LIMITING

Limiting was measured on all channels of the TA-344/G SN 1, SN 2 and SN 3 field wire repeaters. Figures B-134 through B-136 show plots of limiting over the range of input signal levels from -12 to +12 dbm. Absolute limiting commences when the input signal level exceeds +10 dbm.

2.8 TEST OF AM-2262/TT AMPLIFIER ASSEMBLY

2.8.1 GENERAL DESCRIPTION OF EQUIPMENT

The AM-2262/TT amplifier assembly is a lightweight, transistorized, multi-channel repeater unit.

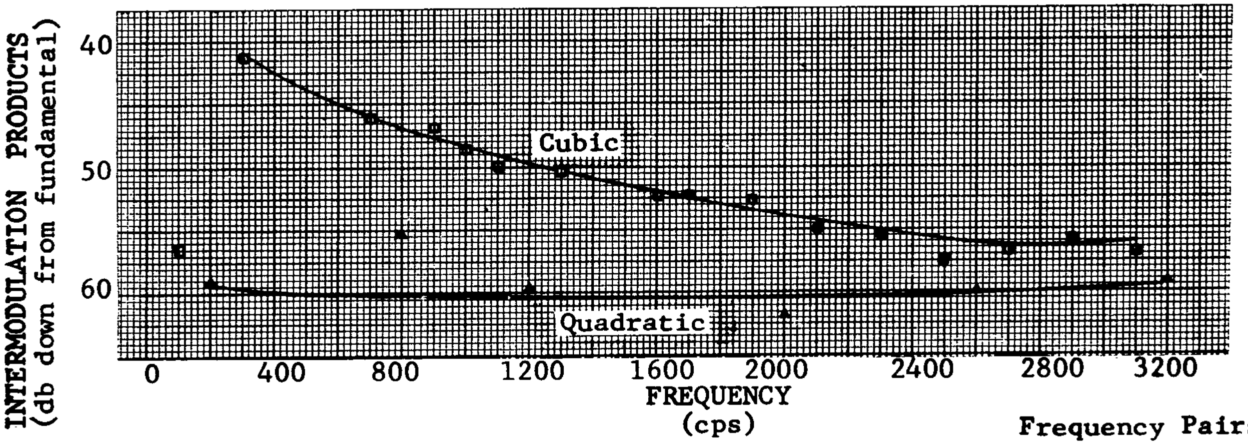


Frequency Pairs

300-500
500-700
900-1100
1200-1400
1500-1700
1900-2100
2300-2500
2700-2900

FIGURE B-131

INTERMODULATION DISTORTION - TA-344/G SN 1
Input Level -18 dbm (total)

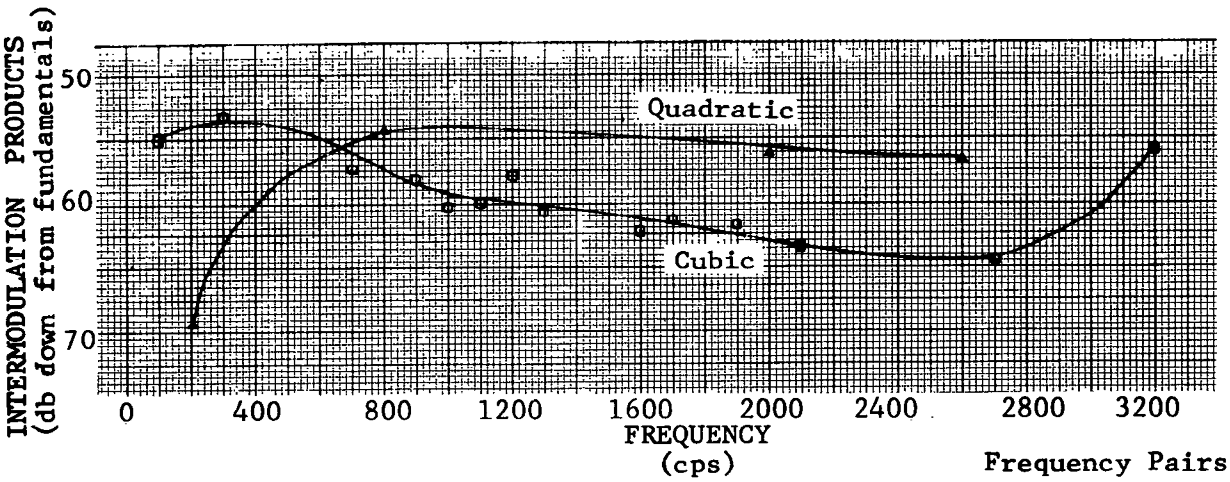


Frequency Pairs

300-500
500-700
900-1100
1200-1400
1500-1700
1900-2100
2300-2500
2700-2900

FIGURE B-132

INTERMODULATION DISTORTION - TA-344/G SN 2
Input Level -18 dbm (total)



Frequency Pairs
300-500
500-700
900-1100
1200-1400
1500-1700
1900-2100
2300-2500
2700-2900

FIGURE B-133

INTERMODULATION DISTORTION - TA-334/G SN 3
Input Level -18 dbm (total)

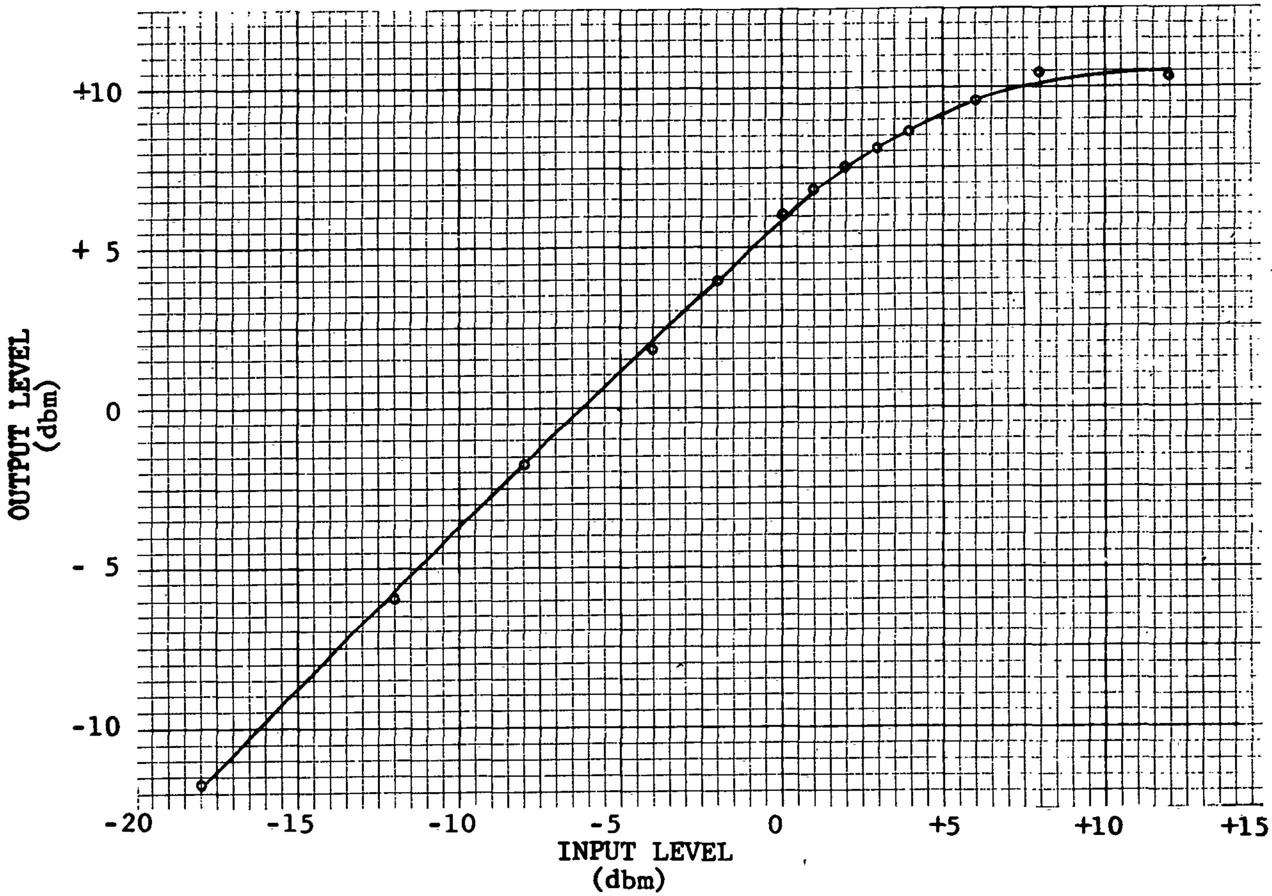


FIGURE B-134

LIMITING - TA-344/G SN 1
Channels Tested 2

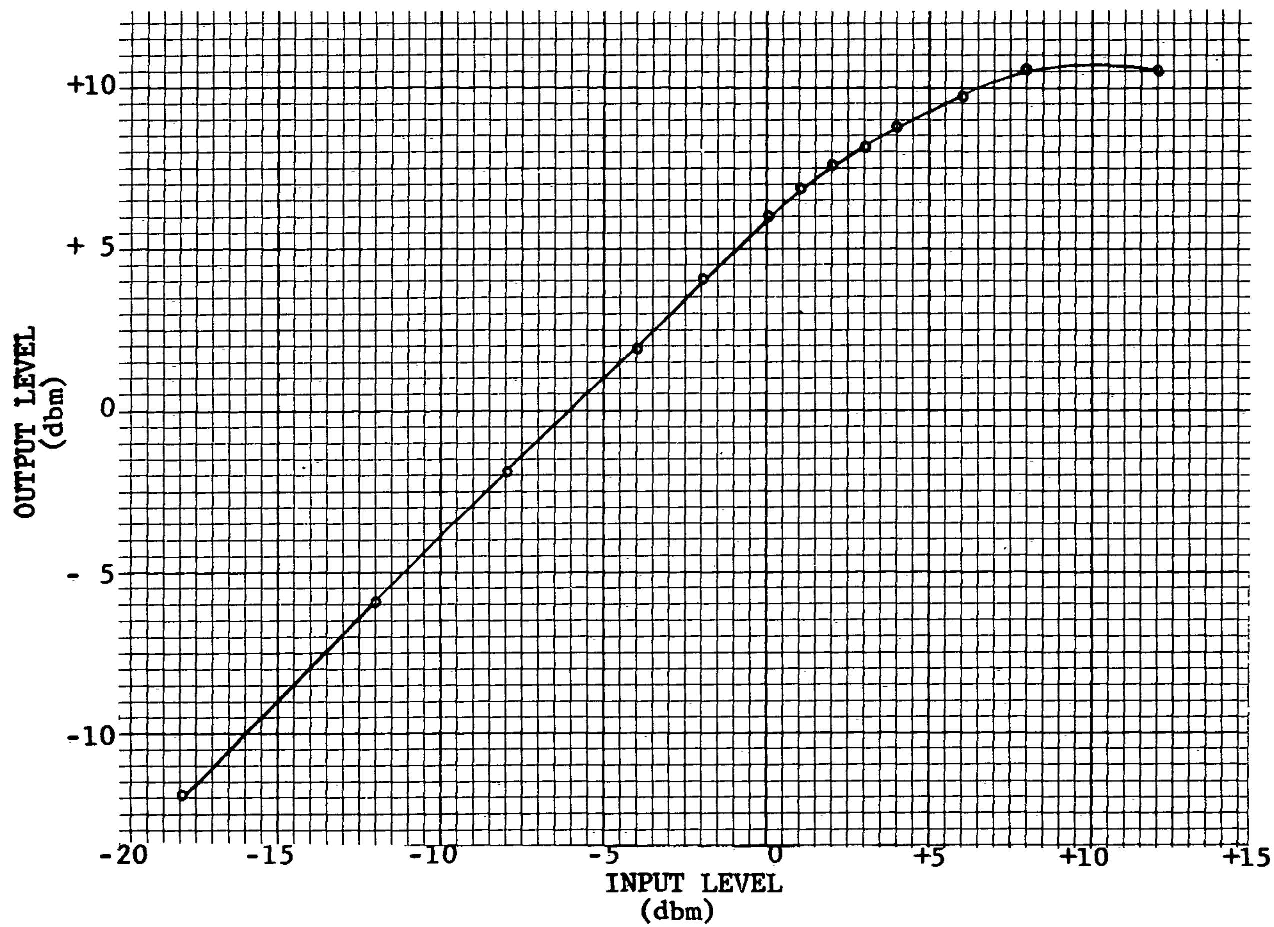


FIGURE B-135

LIMITING - TA-344/G SN 2
Channels Tested 2

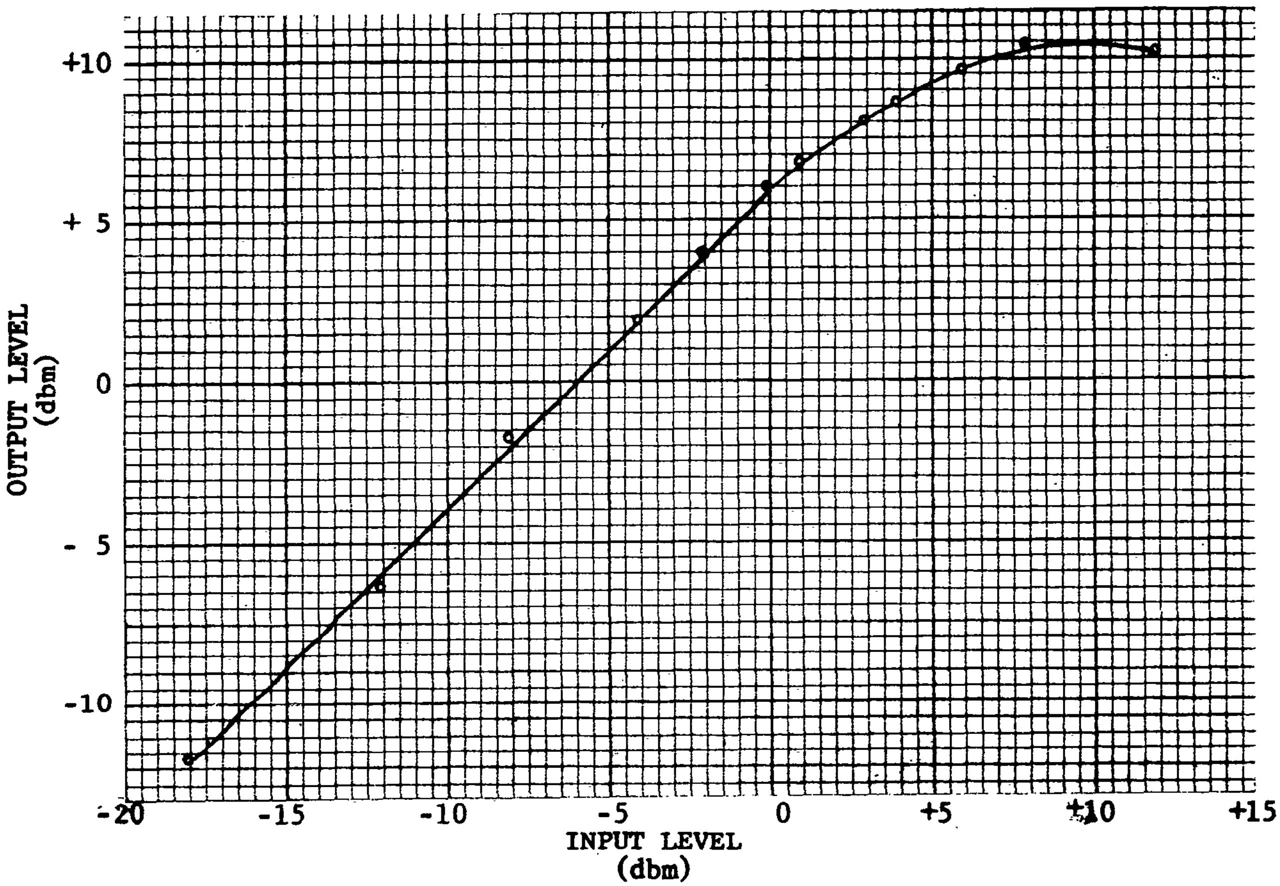


FIGURE B-136

LIMITING - TA-344/G SN 3
Channels Tested 2

2.8.2 OPERATIONAL DESCRIPTION

The AM-2262/TT amplifier assembly is designed for use inside the electronic switchboard at the distribution panel to extend the usable length of WF-16 four conductor field wire. It can also be used to amplify other low level incoming signals that are not capable of actuating signal detectors in the switchboard. Jacks are used to provide compatibility with the electronic switchboards distribution panel. Amplifier units are interchangeable with the TA-344/G field wire repeater.

2.8.3 TECHNICAL DESCRIPTION

Circuit capacity	5 channels
Power	Batteries-external
Amplifiers	Transistorized plug in sub-assemblies
Connections	Jacks

2.8.4 TEST RESULTS - AM-2262/TT

The amplifier modules used in the AM-2262/TT amplifier assembly are identical to those used in the TA-344/G field wire repeater. For transmission characteristic data not presented on the AM-2262/TT, reference can be made to the TA-344/G repeater data presented in Section 2.7 of this annex.

2.8.4.1 FREQUENCY RESPONSE

Frequency response measurements were made on three channels of the AM-2262/TT amplifier assembly using an input signal level of -18 dbm. A plot of the response is shown in Figure B-137. The amplifier gain at 1000 cps was found to be +6.3 db.

2.8.4.2 NOISE

Noise measurements taken on channels of the AM-2262/TT amplifier assembly showed the levels to be below 17 dba (-68 dbm), the sensitivity of the instrumentation.

2.8.4.3 LIMITING

Limiting was measured on three channels of the AM-2262/TT amplifier assembly over the range of input signal levels from -12 to +12 dbm.

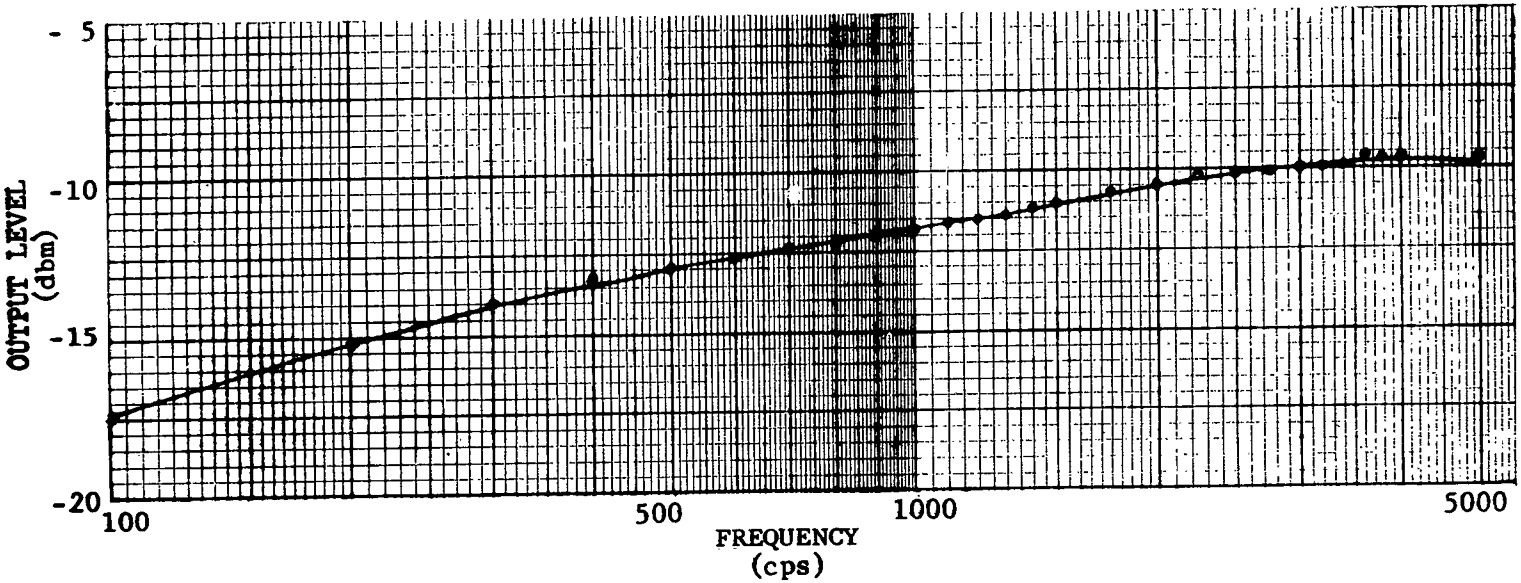


FIGURE B-137

FREQUENCY RESPONSE - AM 2262/TT
Input Level -18 dbm

A plot of the output power level versus input level is shown in Figure B-138. Absolute limiting was found to commence at an input power level of +10 dbm.

2.9 TEST OF SB 1191 ( )/TTC FORWARD AREA MANUAL SWITCHBOARD

2.9.1 GENERAL DESCRIPTION OF EQUIPMENT

The SB 1191 ( )/TTC is a small, lightweight, semi-automatic, twelve line switchboard. It is powered by its own internal battery pack and is fully transistorized.

2.9.2 OPERATIONAL DESCRIPTION

The SB 1191 ( )/TTC is intended for use by lower echelon organizations and requires an operator. In addition to the twelve line capacity, the unit has a conference call feature whereby the operator can switch any or all of the twelve lines into a common circuit without degradation of quality. The SB 1191 ( )/TTC is semi-automatic in that it automatically detects seize, release and recall; however, upon instruction from the subscriber the operator must effect the desired switching function.

2.9.3 TECHNICAL DESCRIPTION

Line or trunk circuits 12
Link circuits 4
Conference link interconnects up to 13 circuits
Input power - self contained BA-30 batteries

2.9.4 TEST RESULTS SB 1191 ( )/TTC

2.9.4.1 INPUT IMPEDANCE

Input impedance measurements were made on six lines of the SB 1191 ( )/TTC amplifier assembly. The impedance was found to vary from a minimum of 525 ohms at 300 cps to a maximum of 646 at 4000 cps, the upper limit of frequency at which the impedance was measured. Figure B-139 shows a plot of the arithmetic mean of the six lines measured.

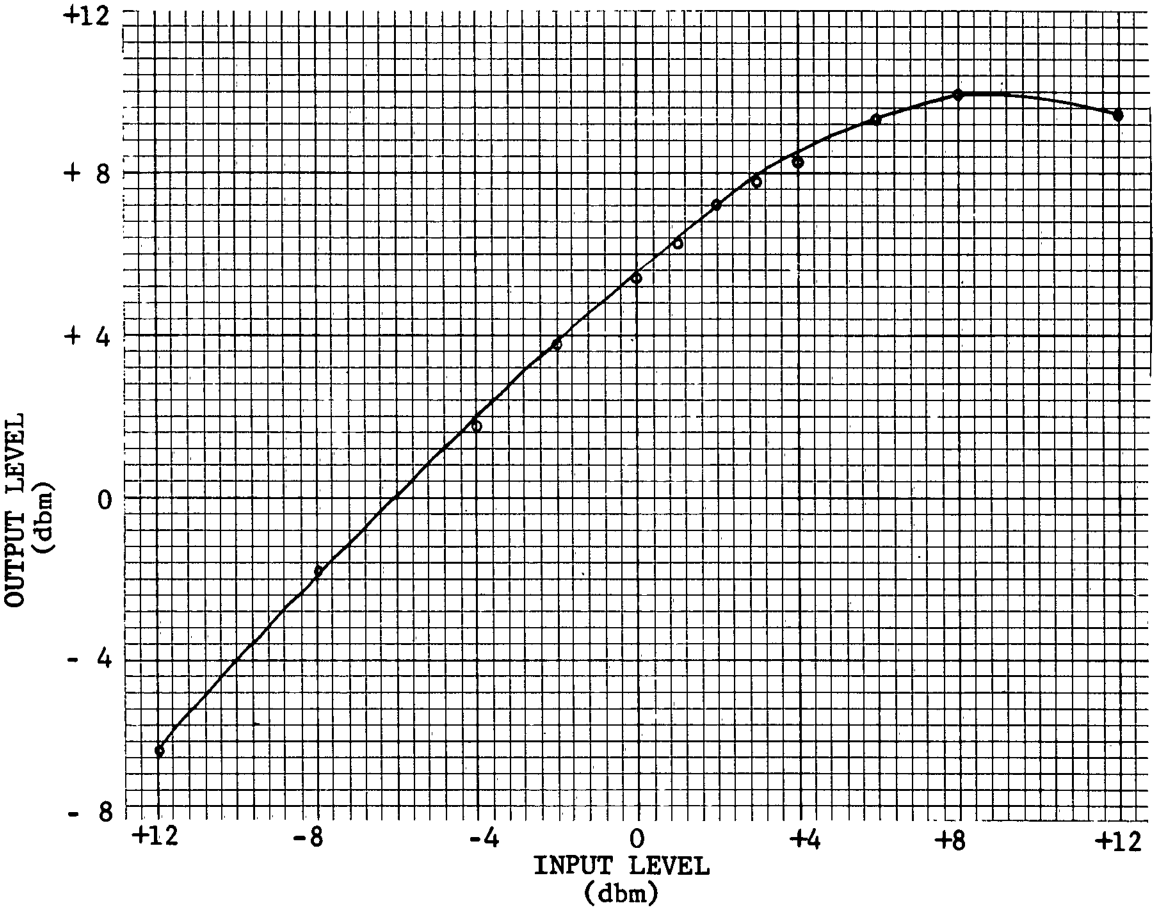


FIGURE B-138

LIMITING - AM 2262/TT
Channels Tested 3

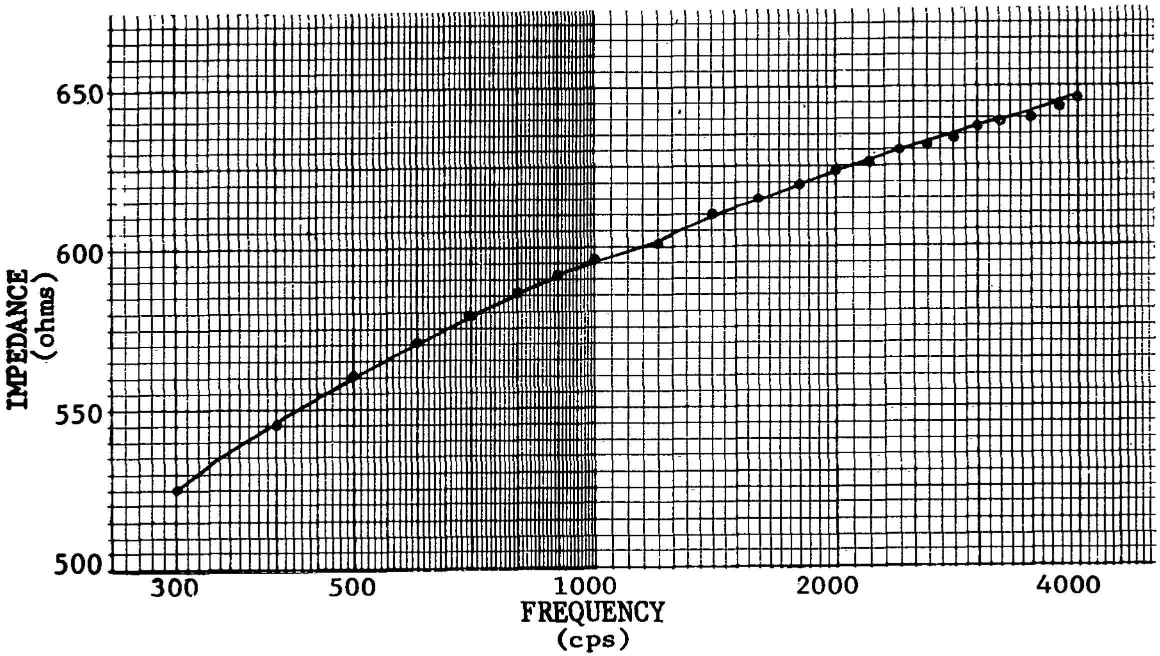


FIGURE B-139

INPUT IMPEDANCE SB 1191 ( )/TTC
Lines Tested 6

2.9.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on six lines of the SB 1191 ( )/TTC amplifier assembly. The impedance was found to vary from a minimum of 521 ohms at 300 cps to a maximum of 650 ohms at 4000 cps, the upper limit of frequency at which the impedance was measured. Figure B-140 shows a plot of the arithmetic mean of the six lines measured.

2.9.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on six lines of the SB 1191 ( )/TTC semiautomatic telephone switchboard. The input signal level used was -4 dbm. Figure B-141 shows a plot of the arithmetic mean obtained on the six lines. The insertion loss at 1000 cps was -1.8 db.

2.9.4.4 HARMONIC DISTORTION

The harmonic distortion produced in the SB 1191 ()/TTC was found to be less than 0.2 per cent, the instrumental accuracy of the testing equipment.

2.9.4.5 TONE DETECTOR SENSITIVITY AND SELECTIVITY

Sensitivity and selectivity measurements were made on the various tone detector circuits of the SB 1191 ( )/TTC. Plots of the data obtained are shown in Figures B-142 through B-144. The sensitivities of the various detectors are in the range of from -35 to -59 dbm.

2.9.4.6 TONE GENERATOR OUTPUT

The frequency and power output of the tone generators of the SB 1191 ( )/TTC were measured. The data obtained are tabulated in Table B-57.

2.9.4.7 CONFERENCE LOAD EFFECT ON COMPLETED CALL

A special test was performed on the SB 1191 ( )/TTC to determine the effect of placing consecutive conference calls on a completed call. It was found that the output signal level of the completed call is decreased by 3.8 db when a conference call is placed on the called line, but that any increase in the conference call load does not effect the output power level on the

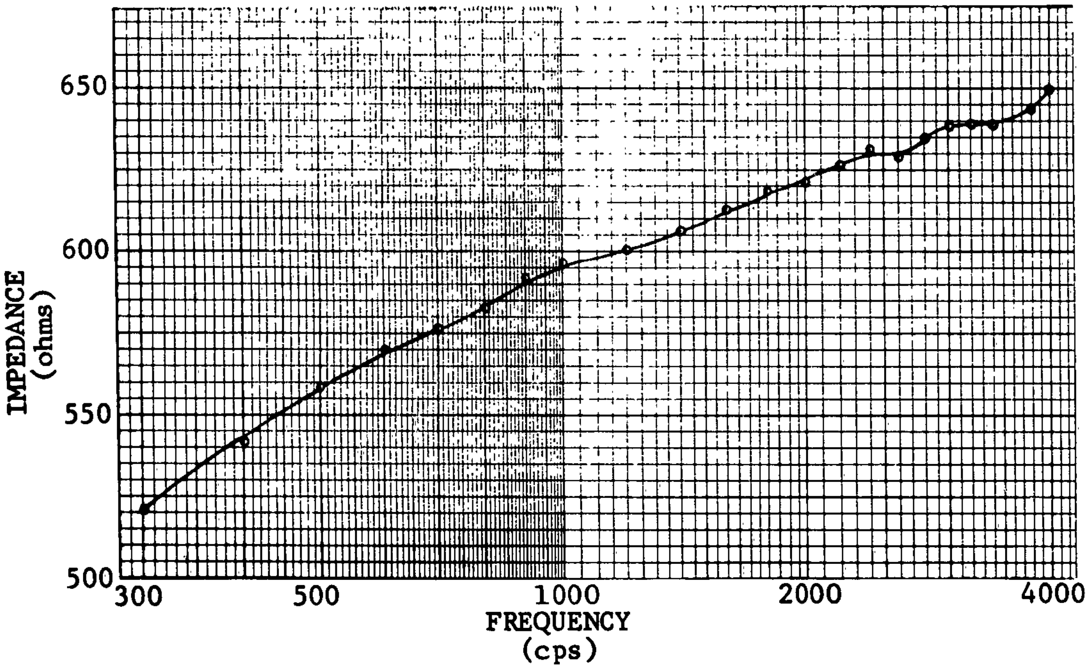


FIGURE B-140

OUTPUT IMPEDANCE - SB 1191 ( )/TTC
Lines Tested 6

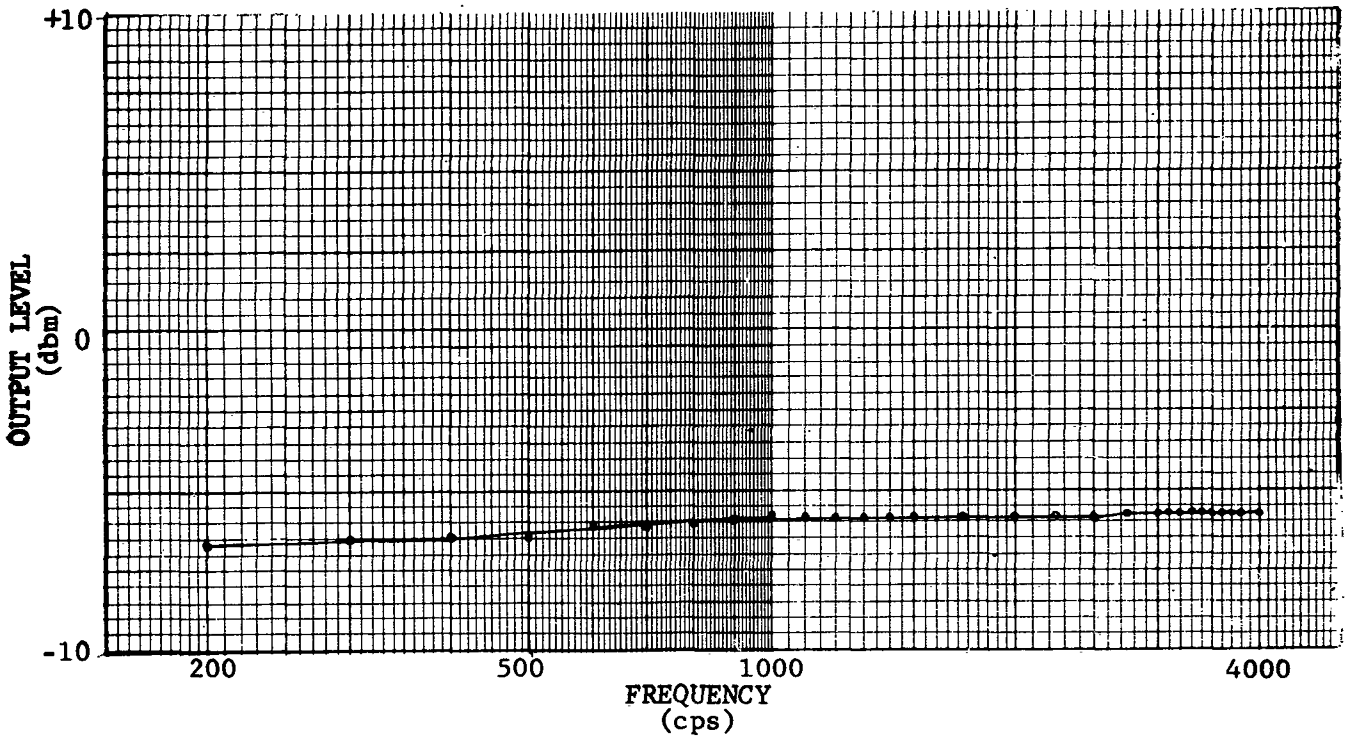


FIGURE B-141

FREQUENCY RESPONSE - SB 1191 ( )/TTC
Lines Tested 6
Input Level -4 dbm

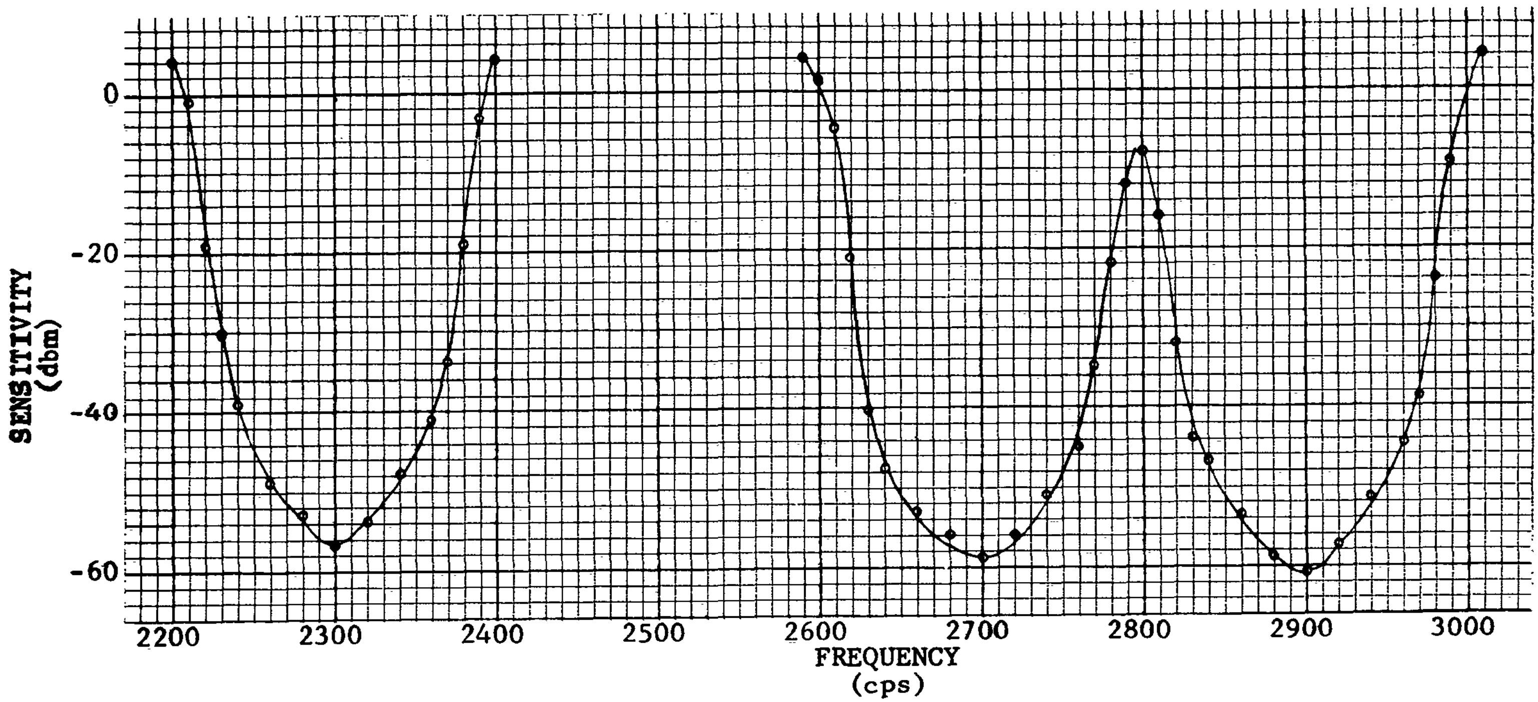


FIGURE B-142

TONE DETECTOR SELECTIVITY CURVES - SB 1191 ( )/TTC
Link Circuits Tested 2

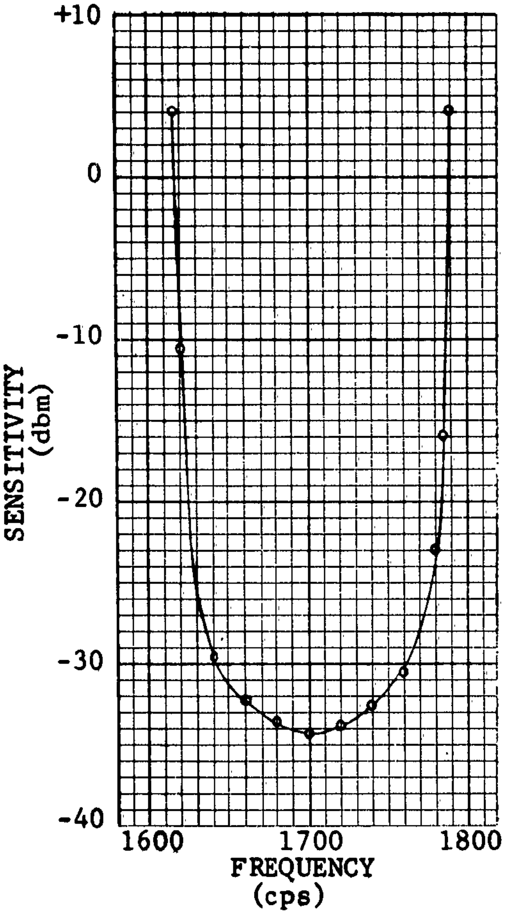


FIGURE B-143

LINE SEIZE TONE DETECTOR SELECTIVITY CURVE
SB 1191 ( )/TTC
Detectors Tested 5

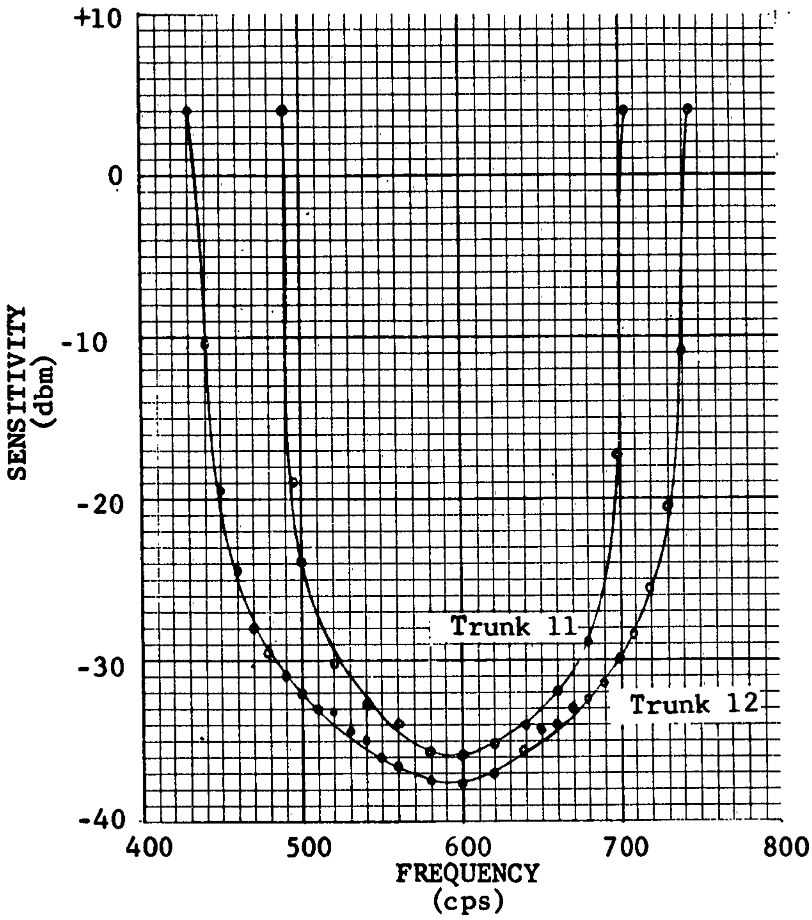


FIGURE B-144

TRUNK RING SIGNAL DETECTOR SELECTIVITY CURVE
SB 1191 ( )/TTC
Trunks Tested 2

TABLE B-57

TONE GENERATOR OUTPUT - SB 1191 ( )/TTC

TONE GENERATOR	FREQUENCY (cps)	SIGNAL LEVEL (dbm)
Trunk Seize	1688	-7.9
Ring Signal	641	+3.0

on the called line. The data obtained on this test is tabulated in Table B-58. It was also determined that the above data is true if all the conference lines are terminated with a direct short circuit instead of nominal 600 ohm loads.

2.10 TEST RESULTS WF-16

Transmission tests were performed using combinations of stranded and solid and stranded only lengths of WF-16 field wire. It was established during the testing that the type of wire used did not measurably effect the data obtained.

2.10.1 IMPEDANCE

Impedance measurements were made under various climatic conditions (wet-dry; hot-cool) on the 1 and 8 mile lengths of WF-16 field wire. It was noted that the impedance decreased with increase in frequency due to the capacitive reactance of the wire. Figure B-145 is a plot of the data obtained for dry-hot and cool conditions. The wet-dry characteristics were found to be very good. Tests run under cool (70°) conditions, wet and dry, showed no measurable variation.

2.10.2 FREQUENCY RESPONSE

Frequency response measurements were made on various lengths of WF-16 field wire using a signal level of -4 dbm and 600 ohm termination. It was found that attenuation increased as was predicted with both frequency and wire length. Plots of frequency response for wet-cool and dry-cool conditions are shown in Figures B-146 and B-147. A plot of the data obtained for a dry-hot condition is shown in Figure B-148. As can be noted by the plots variations of climatic conditions have little effect upon frequency response.

At any specific frequency attenuation increased with wire length. A plot of data showing this phenomena is shown in Figure B-149.

2.10.3 CROSSTALK LOSS

Near and far end crosstalk loss measurements were made on various lengths of WF-16 field wire. The crosstalk loss on all lengths measured was found to be greater than 47 db down from the disturbing signal level of -4 dbm. The data obtained is tabulated in Tables B-59 and B-60.

TABLE B-58

CONFERENCE LOAD EFFECT ON COMPLETED CALL
SB 1191 ( )/TTC

INPUT SIGNAL LEVEL AT 1 KC	COMPLETED CALL	CONFERENCE LOAD LINE NUMBER *	OUTPUT SIGNAL LEVEL LINE No. 2 (dbm)
-4	Line 1 to 2	None	-5.6
-4	" " "	3	-9.4
-4	" " "	3,4	-9.4
-4	" " "	3,4,5	-9.4
-4	" " "	3,4,5,6	-9.4
-4	" " "	3,4,5,6,7	-9.4
-4	" " "	3,4,5,6,7,8	-9.4
-4	" " "	3,4,5,6,7,8,9	-9.4
-4	" " "	3,4,5,6,7,8,9,10	-9.4
-4	" " "	3,4,5,6,7,8,9,10,11	-9.4
-4	" " "	3,4,5,6,7,8,9,10,11,12	-9.4
-4	" " "	3 through 12 plus operator	-9.4

* All conference lines terminated with a 600 ohm resistor

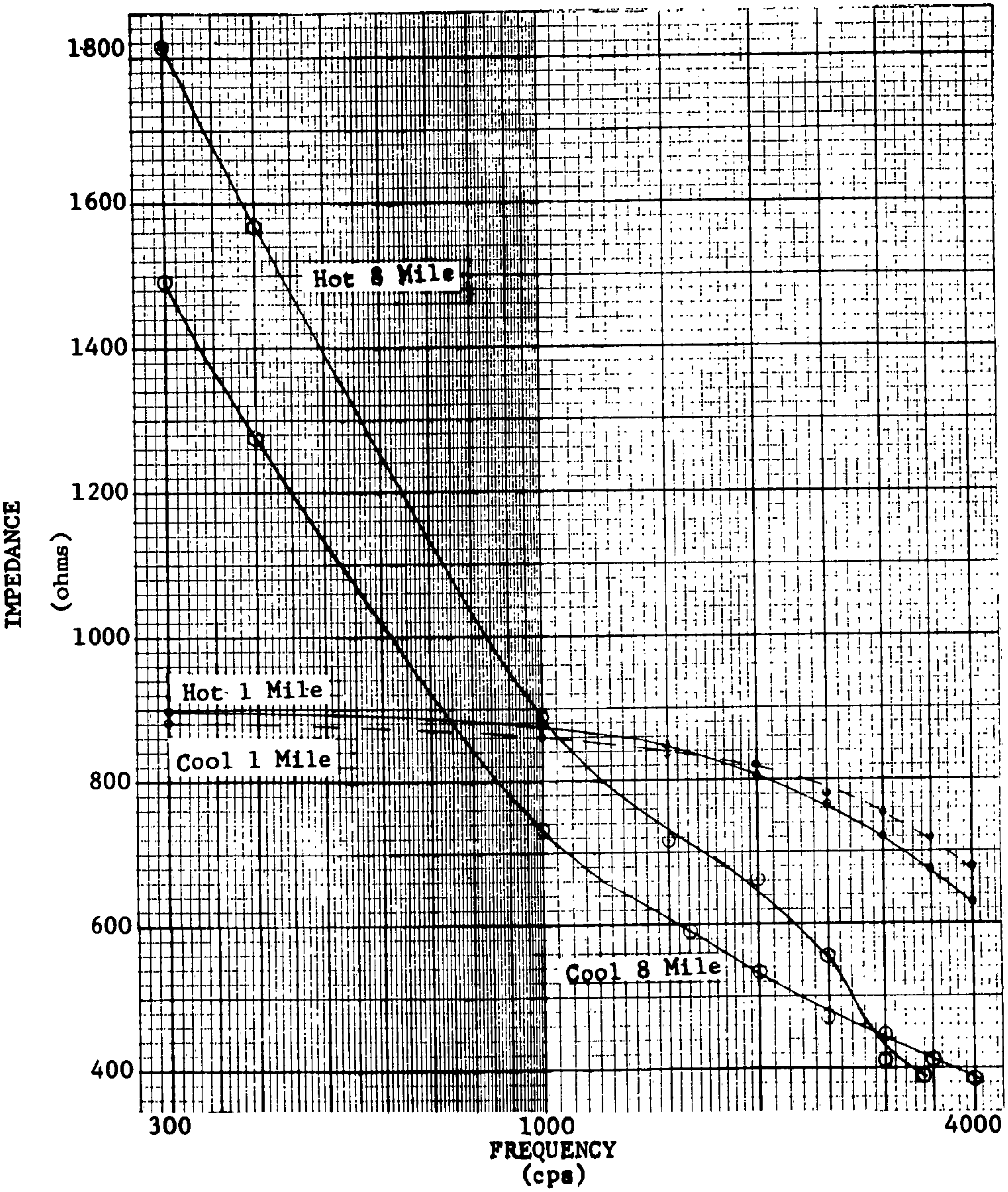


FIGURE B-145

IMPEDANCE WF-16 FIELD WIRE
Dry - Cool and Hot
- Cool 71-72°F
- Hot 107-124°F

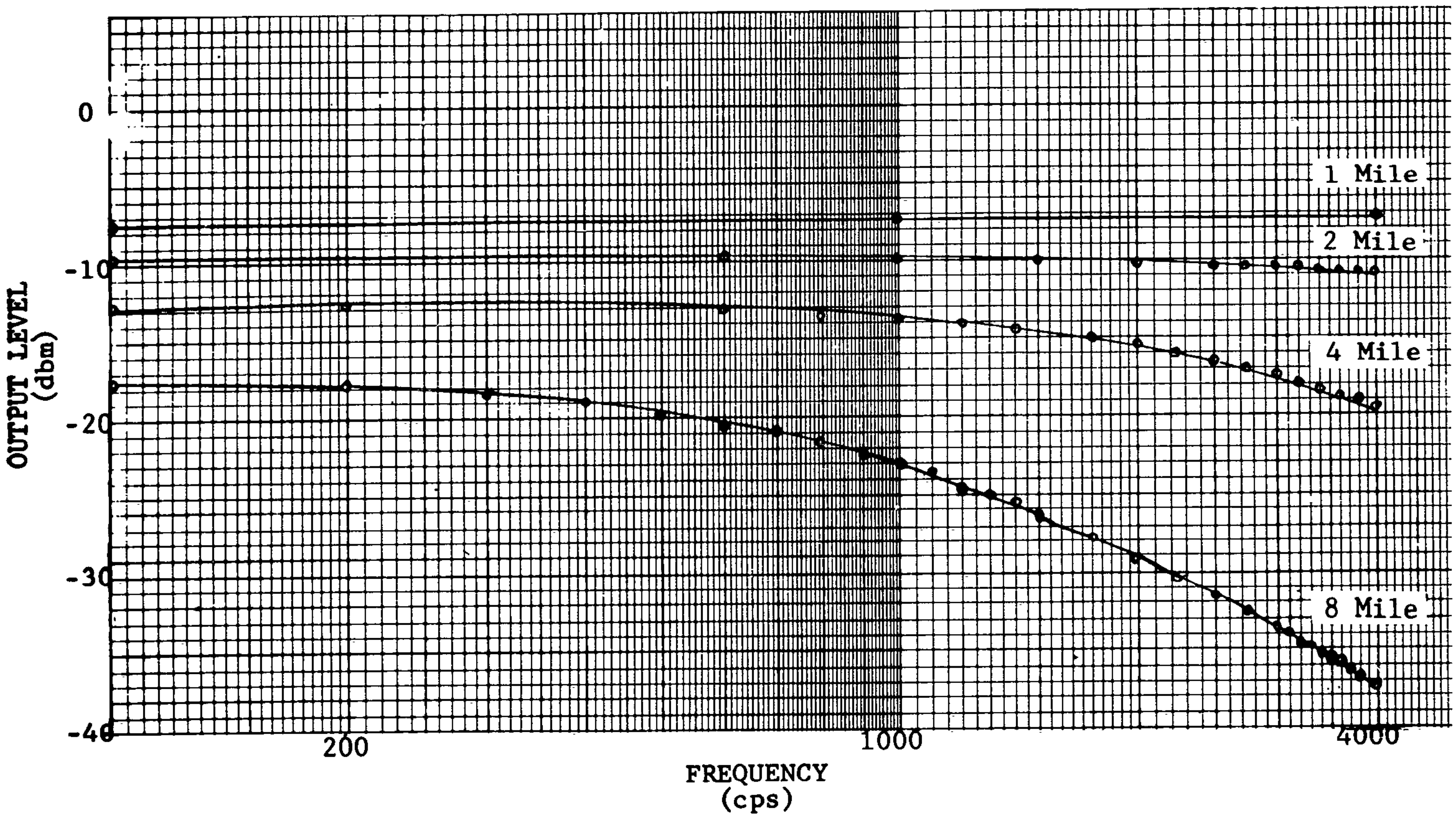


FIGURE B-146

FREQUENCY RESPONSE WF-16
Wet-Cool Conditions
Temperature 62-70°F
Input Signal Level -4 dbm

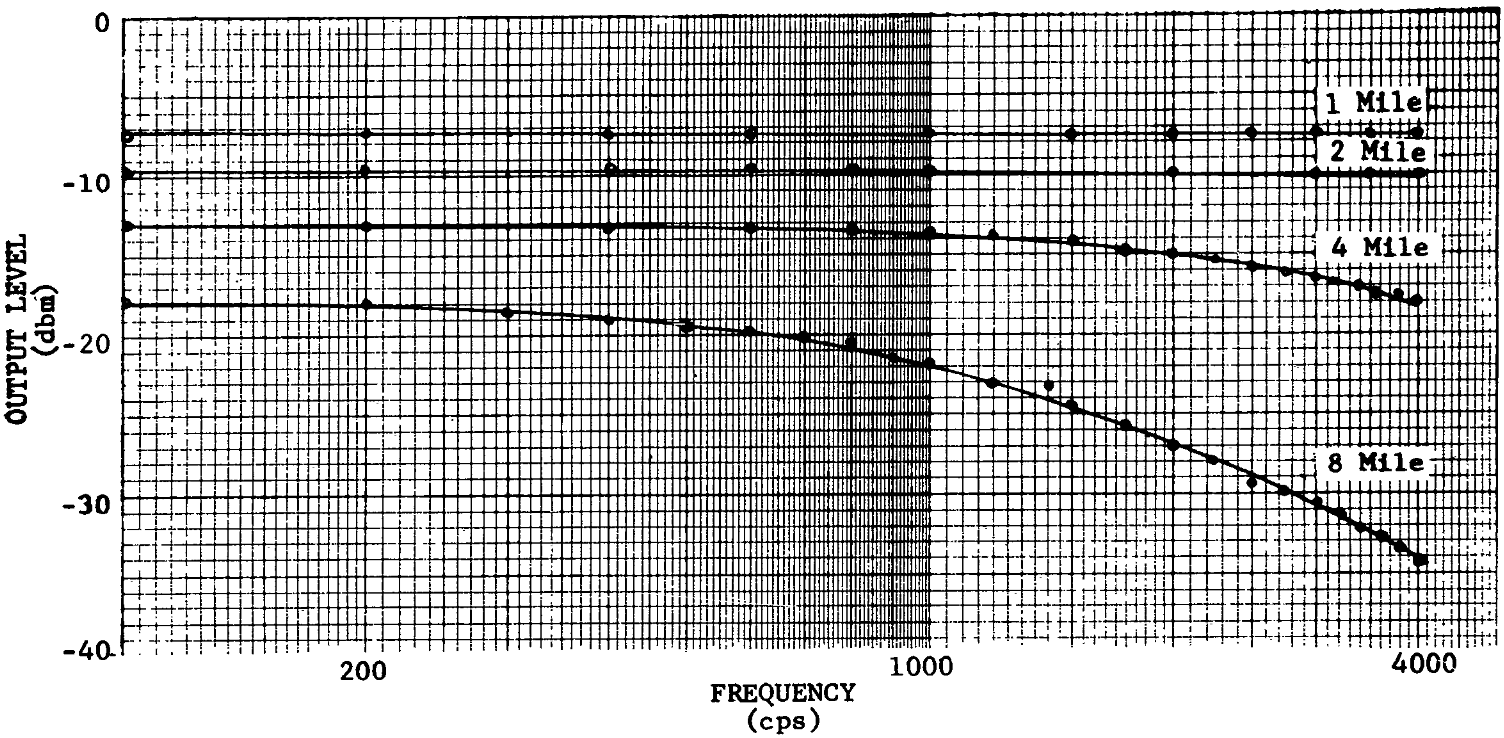


FIGURE B-147

FREQUENCY RESPONSE WF-16
Dry-Cool Conditions
Temperature 71-72°F
Input Signal Level -4 dbm

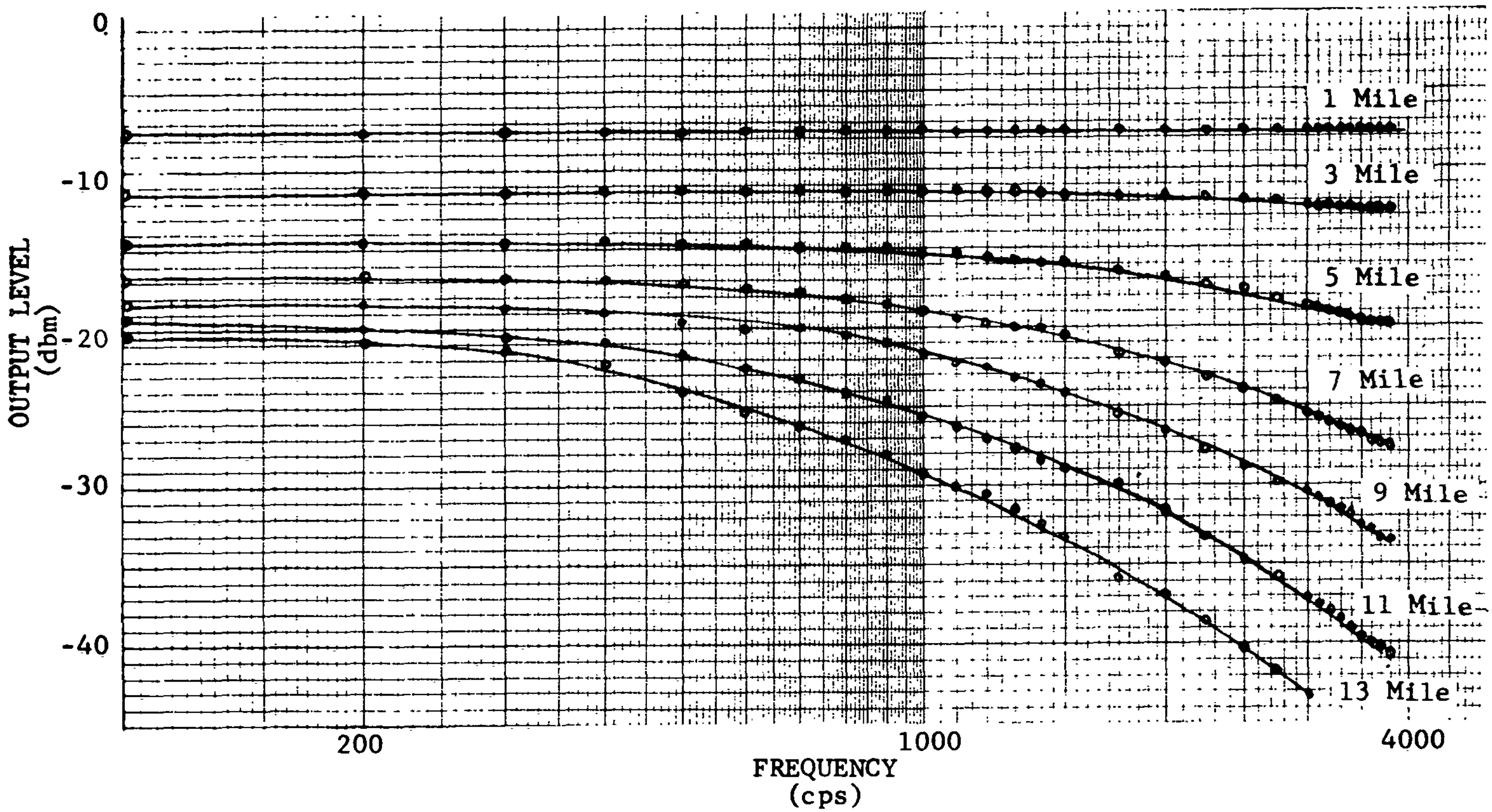


FIGURE B-148

FREQUENCY RESPONSE WF-16
Dry-Hot Conditions
Temperature 107-121°F
Input Signal Level -4 dbm

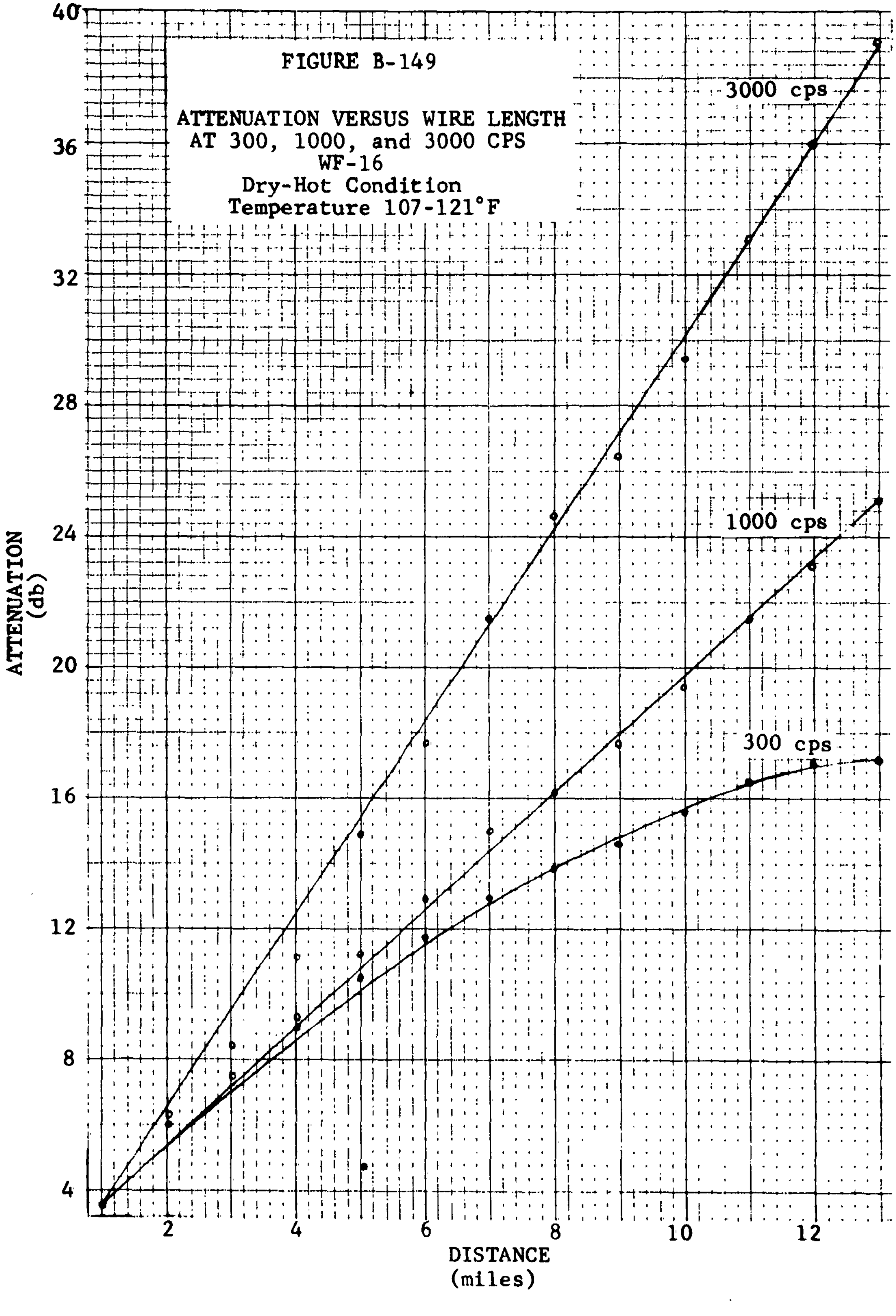


FIGURE B-149
ATTENUATION VERSUS WIRE LENGTH
AT 300, 1000, and 3000 CPS
WF-16
Dry-Hot Condition
Temperature 107-121°F
3000 cps
1000 cps
300 cps
ATTENUATION
(db)
40
36
32
28
24
20
16
12
8
4
2
4
6
8
10
12
DISTANCE
(miles)

TABLE B-59

NEAR END CROSSTALK LOSS - WF-16 FIELD WIRE
Input Level -4 dbm

FREQUENCY (cps)	CROSSTALK LOSS (db down from input signal level)				
	1 Mile	3 Miles	5 Miles	8 Miles	10 Miles
300	76.0	---	67.5	66.0	71.0
600	70.0	92.0	62.0	59.8	65.0
1000	65.0	85.0	57.5	55.8	61.0
1200	64.0	82.0	56.0	54.7	60.0
1500	62.0	79.0	54.0	53.2	58.5
1700	61.0	77.0	53.5	52.7	58.0
1900	60.0	76.0	53.0	52.1	57.5
2100	59.0	74.5	52.5	51.8	56.5
2300	59.0	73.5	52.0	51.3	56.5
2500	58.0	72.5	51.5	51.0	56.0
2700	58.0	72.0	51.0	50.8	56.0
2900	57.5	70.5	51.0	50.3	56.0
3100	57.0	70.0	50.5	50.2	56.0
3300	57.0	70.0	50.0	50.1	56.0
3500	56.5	69.5	50.0	50.1	56.0

TABLE B-60

FAR END CROSSTALK LOSS - WF-16 FIELD WIRE
Input Level -4 dbm

FREQUENCY (cps)	CROSSTALK LOSS (db down from far end disturbing signal level)				
	1 Mile	3 Miles	5 Miles	8 Miles	10 Miles
300	71.4	79.0	78.5	63.2	55.5
600	65.5	73.0	72.5	58.9	52.0
1000	62.0	69.0	67.5	56.5	49.5
1200	60.0	66.5	66.0	55.5	49.5
1500	58.0	65.5	64.5	54.7	48.0
1700	57.0	64.5	63.0	52.6	47.5
1900	56.5	64.0	62.5	52.7	46.5
2100	56.0	63.5	62.0	51.7	46.5
2300	55.0	63.0	62.0	50.7	46.0
2500	54.5	62.5	61.5	49.9	45.0
2700	54.5	62.0	62.0	49.3	43.5
2900	53.5	62.0	61.5	48.4	42.5
3100	53.5	62.0	62.0	48.0	43.0
3300	53.0	61.0	62.5	47.8	42.5
3500	53.0	61.5	63.0	47.6	42.5

2.10.4 NOISE

Noise measurements made on various lengths of WF-16 field wire showed the noise levels to be below 17 dba (-68 dbm), the sensitivity of the instrumentation described in the test procedures of Annex A.

2.10.5 PHASE DISTORTION

Envelope delay time in microseconds was measured for various lengths of WF-16 field wire using the Phazor 200-AB phasemeter (accuracy 1.0 degree). A plot of the data obtained is shown in Figure B-150. The plot is only indicative of the trend as the accuracy (55 microseconds) of the test equipment precluded the collection of precise data.

2.11 TEST OF SB-22/PT

2.11.1 GENERAL DESCRIPTION OF EQUIPMENT

The SB-22/PT is a lightweight, local battery field type manual telephone switchboard which provides facilities for interconnecting twelve circuits.

2.11.2 OPERATIONAL DESCRIPTION

The SB-22/PT manual telephone switchboard is used to interconnect local battery telephone lines, remote controlled radio circuits and voice frequency teletypewriter circuits. The connection of the calls on the switchboard is done in a normal fashion. When connecting local battery lines the SB-86/P manual switchboard connects the SB-22 to the TTC-7 manual switchboard.

2.11.3 TECHNICAL DESCRIPTION

Lines or trunks	12
Manual ringing	20 cps 90-100 volts (hand operated generator)

2.11.4 TEST RESULT SB-22/PT

2.11.4.1 INPUT-OUTPUT IMPEDANCE

Input and output impedance measurements were made on random combinations of all lines of the SB-22/PT. A plot of the most probable mean of the impedance versus frequency is shown in Figure B-151. The

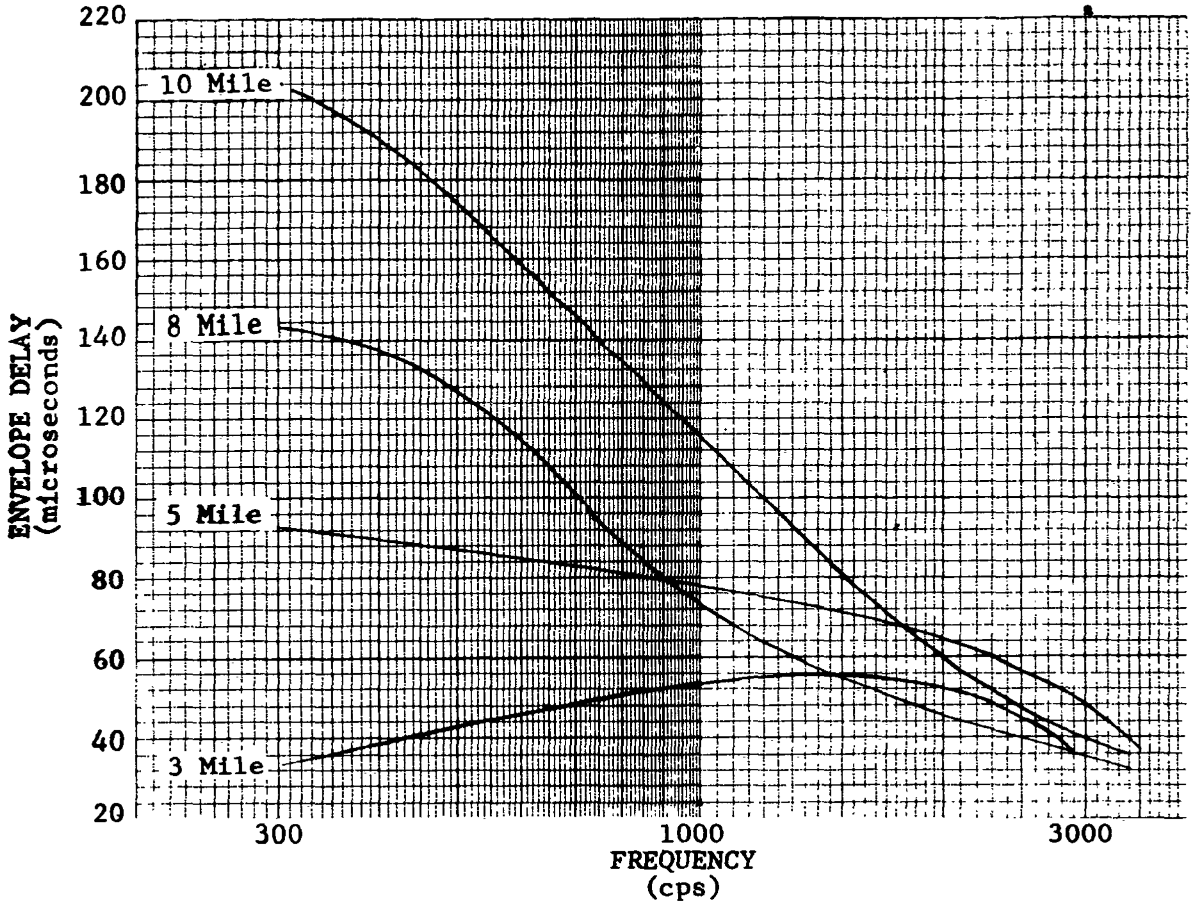


FIGURE B-150

ENVELOPE DELAY WF-16 FIELD WIRE

Note: Information is indicative only, precise data not obtainable

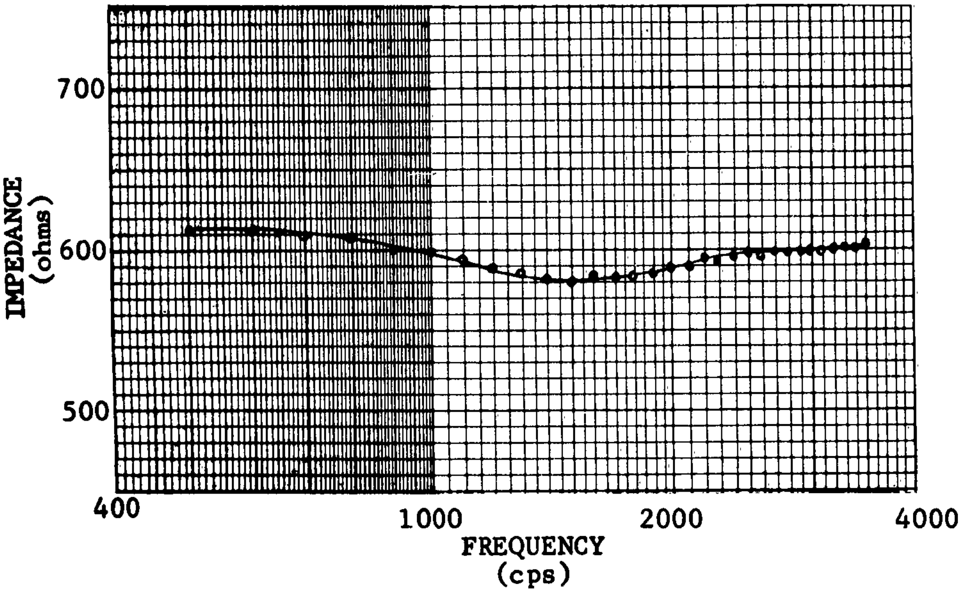


FIGURE B-151

INPUT-OUTPUT IMPEDANCE - SB-22/PT

impedance varied from a minimum of 580 ohms at 1500 cps to a maximum of 612 ohms at 500 cps.

2.11.4.2 FREQUENCY RESPONSE

The frequency response of the SB-22/PT using an input level of -4 dbm was measured on random line to line combinations and was found to be from 300 to 3500 cps within the instrumental accuracy of the testing equipment.

2.11.4.3 Tests to determine crosstalk loss, harmonic distortion, intermodulation distortion, noise and phase distortion were conducted on random line to line combinations of the SB-22/PT. The results of these tests were found to be below the instrumental limits.

2.11.4.4 LONGITUDINAL BALANCE

Longitudinal balance measurements were taken between all line to line combinations and ground on the SB-22/PT. All measurements showed the longitudinal balance to be greater than 64 db below the reference signal level. The measurements taken are tabulated in Table B-61.

2.12 TEST OF SB-86/P MANUAL SWITCHBOARD

2.12.1 GENERAL DESCRIPTION OF EQUIPMENT

The SB-86/P is a local or common battery field type manual switchboard which provides facilities for interconnecting thirty circuits. Using auxiliary equipment, up to sixty circuits may be interconnected.

2.12.2 OPERATIONAL DESCRIPTION

The SB-86/P manual telephone switchboard is used to interconnect lines, and will function with the SB-22/PT manual telephone switchboard and the AN/TTC-7 manual switchboard. The SB-86/P is also used to interconnect voice frequency teletypewriter lines.

2.12.3 TECHNICAL DESCRIPTION

Lines	30 with 1 jack field section	
	60 with 2 jack field section	
Ringing Facilities		
Manual Ringing		Hand generator
Automatic Ringint		20 cps vibrator in power pack

TABLE B-61

LONGITUDINAL BALANCE - SB-22/PT

LINE	LONGITUDINAL BALANCE (db below reference level)
1	65.7
2	66.4
3	69.0
4	65.7
5	66.0
6	71.2
7	67.6
8	64.4
9	68.4
10	68.4
11	71.2
12	65.7
AVERAGE FOR ALL LINES	67.5

Power Requirements

Common battery signalling	20-26.5 Vdc
Magneto signalling	15-26.5 Vdc
Operators telephone	3 Vdc
Night alarm & panel lights	3 Vdc

2.12.4 TEST RESULTS SB-86/P

2.12.4.1 INPUT-OUTPUT IMPEDANCE

Input-output impedance measurements were made on random line to line combinations of the SB-86/P. A plot of the most probable mean of the input-output impedance versus frequency and the range defining the range of excursion of sample means with a 95 per cent confidence level is shown in Figure B-152. The impedance varied from a minimum of 261 ohms at 300 cps to a maximum of 635 ohms at 3500 cps.

2.12.4.2 FREQUENCY RESPONSE

Frequency response measurements were made on random line to line combinations of the SB-86/P using an input level of -4 dbm. A plot of the frequency response is shown in Figure B-153 and the range defining the excursion of sample means with a 95 per cent confidence level is shown. The response is essentially flat from 300 to 3500 cps.

2.12.4.3 CROSSTALK LOSS

Measurements were made of near end and far end crosstalk loss on random line to line combinations of the SB-86/P. An input level of -4 dbm was used. The only crosstalk detectable was in -70 db range and, therefore, is not plotted.

2.12.4.4 HARMONIC DISTORTION AND NOISE

The harmonic distortion and noise produced in the SB-86/P was lower than the instrumental error of the test equipment.

2.12.4.5 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on random line to line combinations of the SB-86/P. A pair of fundamental frequencies (f_1 and f_2), separated by 200 cps and producing a total signal level of

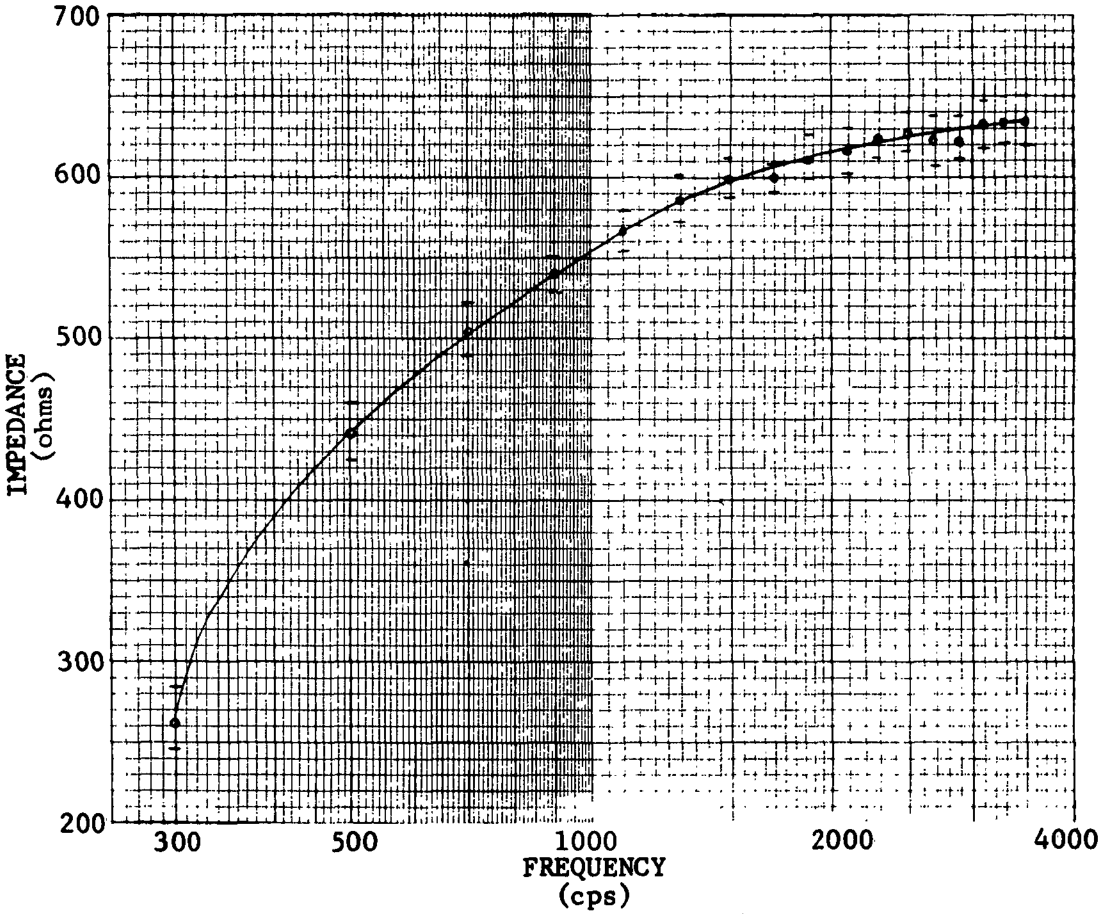


FIGURE B-152

INPUT-OUTPUT IMPEDANCE - SB-86/P

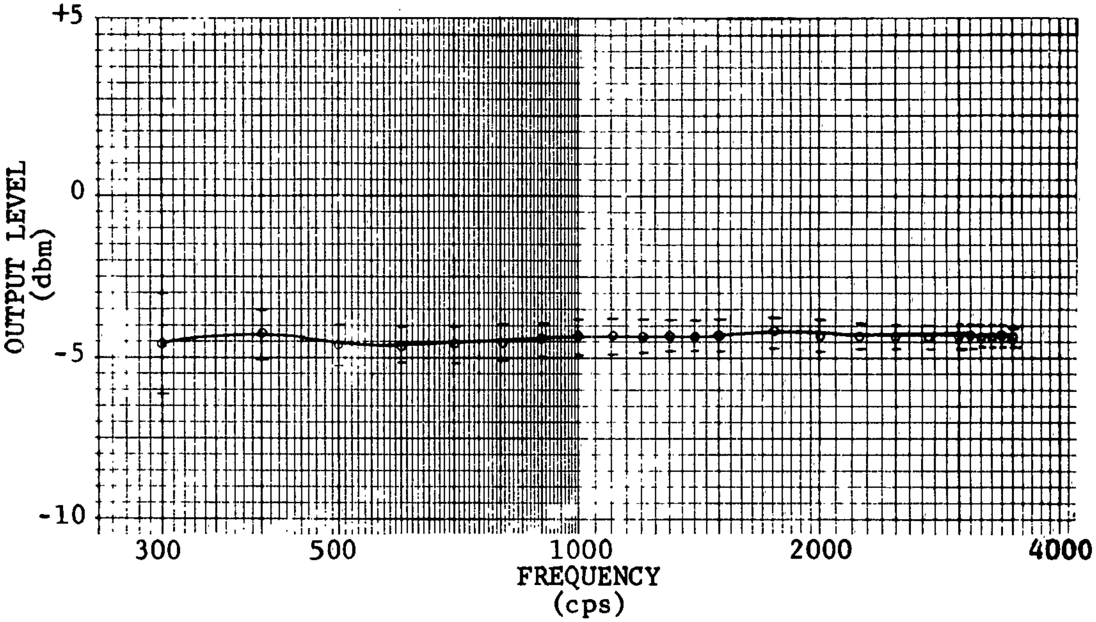


FIGURE B-153

FREQUENCY RESPONSE - SB-86/P
Input Level -4 dbm

-4 dbm, were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$) cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$) and quartic $3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distortion products falling within the equipment passband were measured for each frequency pair as shown in Figure B-154.

2.12.4.6 PHASE DISTORTION

The envelope delay time was measured on random line to line combinations of the SB-86/P using the Maxon model 901 phasemeter (accuracy 0.1 degrees). The envelope delay time of the SB-86/P was found to be 404 microseconds at 300 cps and to drop rapidly to near zero at 700 cps. A plot of the envelope delay time is shown in Figure B-155.

2.13 TEST OF AN/TTC-7

2.13.1 GENERAL DESCRIPTION OF EQUIPMENT

The AN/TTC-7 is a complete telephone central office consisting of switchboards, batteries, power panels, line relay banks and a distribution frame. The unit provides for the manual control of 200 local lines, 20 supervisory trunks and 20 manual or dial trunks. Power for the central is provided by four 12 volt batteries and rectifier.

2.13.2 OPERATIONAL DESCRIPTION

The AN/TTC-7 may be combined with other AN/TTC-7 units to provide facilities for up to 960 lines, 100 supervisory trunks and 100 manual or dial trunks. A common battery circuit provides a means of connecting a common battery phone to a jack in the switchboard and contains the relay equipment necessary to give the operator visual and audible signals of incoming calls. Another circuit is provided which allows termination of common battery or local battery lines and magneto lines. The termination function is chosen by switch operation.

2.13.3 TECHNICAL DESCRIPTION

Lines	
Common battery	100
Common or local battery	100
Trunks	
Manual or dial	20
Plug supervision	20

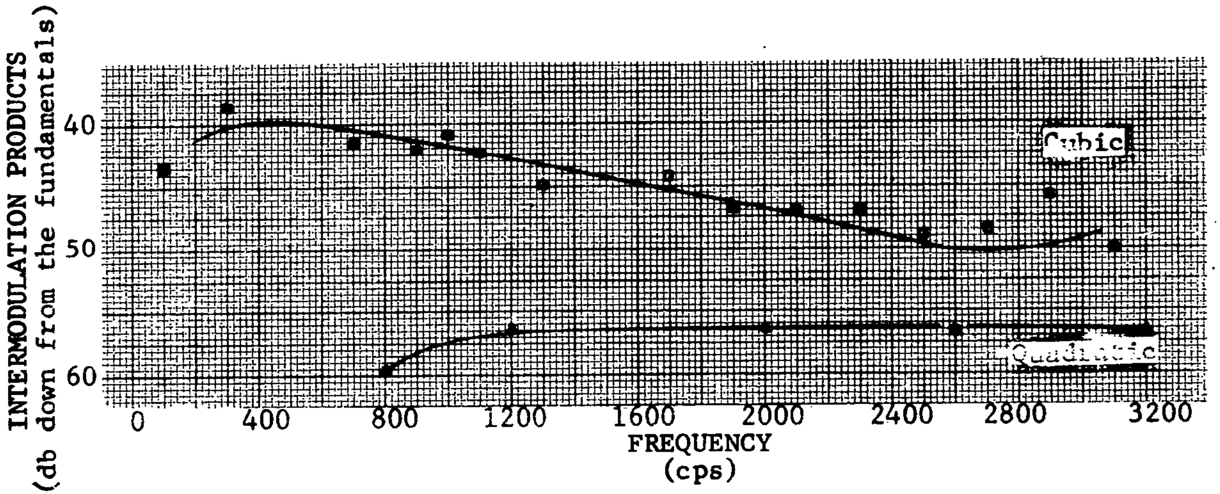


FIGURE B-154

INTERMODULATION DISTORTION - SB-86/P
Input Level -4 dbm (total)

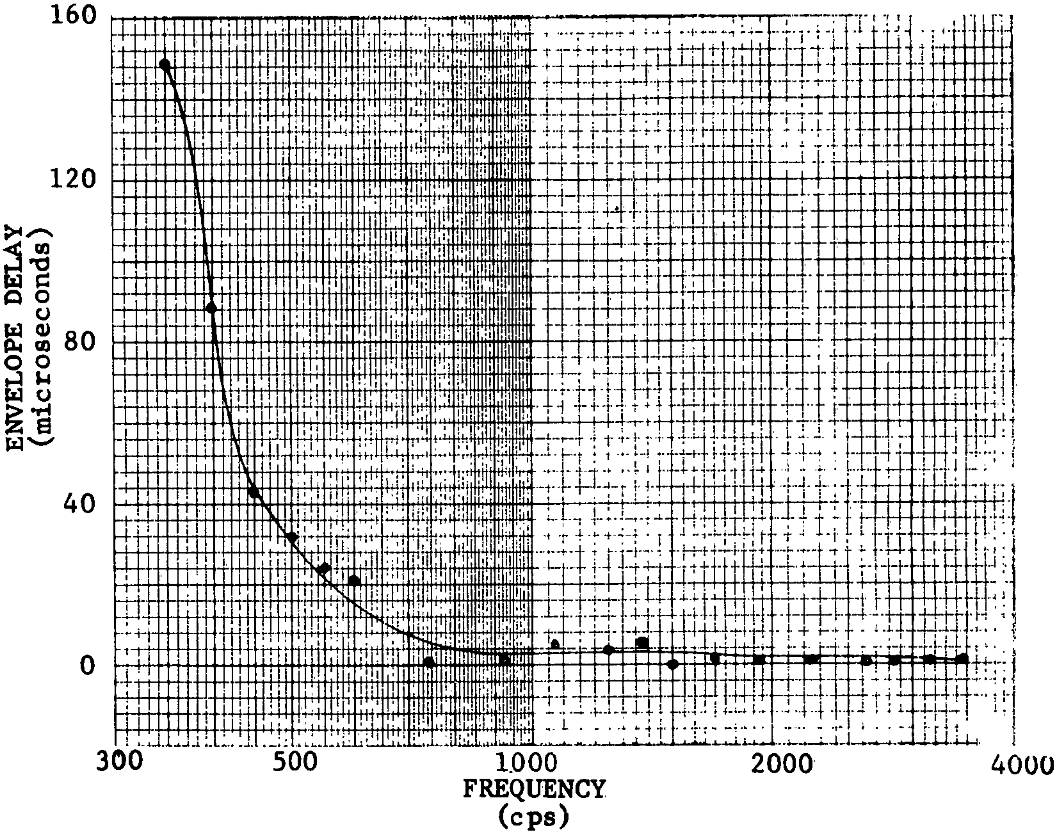


FIGURE B-155

ENVELOPE DELAY TIME - SB-86/P
Input Level -4 dbm

Cord Circuits	15 per position
Type of operation	Manual
Multiple Arrangement	2 or 4 panels
Dial speed	8-12 pulses
Operating limits of relays	44-54 volts
Minimum leakage resistance	10,000 ohms
Maximum loop resistance	
Common battery & trunk circuits	1500 ohms
Local battery	3500 ohms

2.13.4 PHYSICAL DESCRIPTION

The overall weight of the AN/TTC-7 system is 2000 pounds. The unit may be installed in a van as a mobile control center or in a building as a semi-permanent installation.

2.13.5 TEST RESULTS AN/TTC-7

2.13.5.1 INPUT-OUTPUT IMPEDANCE

Input-output impedance measurements were made on all trunk to trunk and random line to line combinations of the AN/TTC-7. Figure B-156 is a plot of the most probable mean of the impedance of trunk circuits of the AN/TTC-7. The impedance varied from a minimum of 666 ohms at 3500 cps to a maximum of 978 ohms at 300 cps. Figure B-157 is a plot of the most probable mean of the impedance of line circuits of the AN/TTC-7. The line circuit impedance varied from a minimum of 630 ohms at 3500 cps to a maximum of 822 ohms at 3000 cps.

2.13.4.2 FREQUENCY RESPONSE

Frequency response measurements were made on random line to line combinations of the AN/TTC-7 using an input level of -4 dbm. A plot of the frequency response is shown in Figure B-158. Since the average range of the excursion of the means was only 0.06 db, the range is not shown in the figure. The response was flat ($\pm$ 0.50 db) from 300 to 3500 cps.

2.13.4.3 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on random line to line combinations of the AN/TTC-7. A pair of fundamental frequencies (f_1 and f_2)

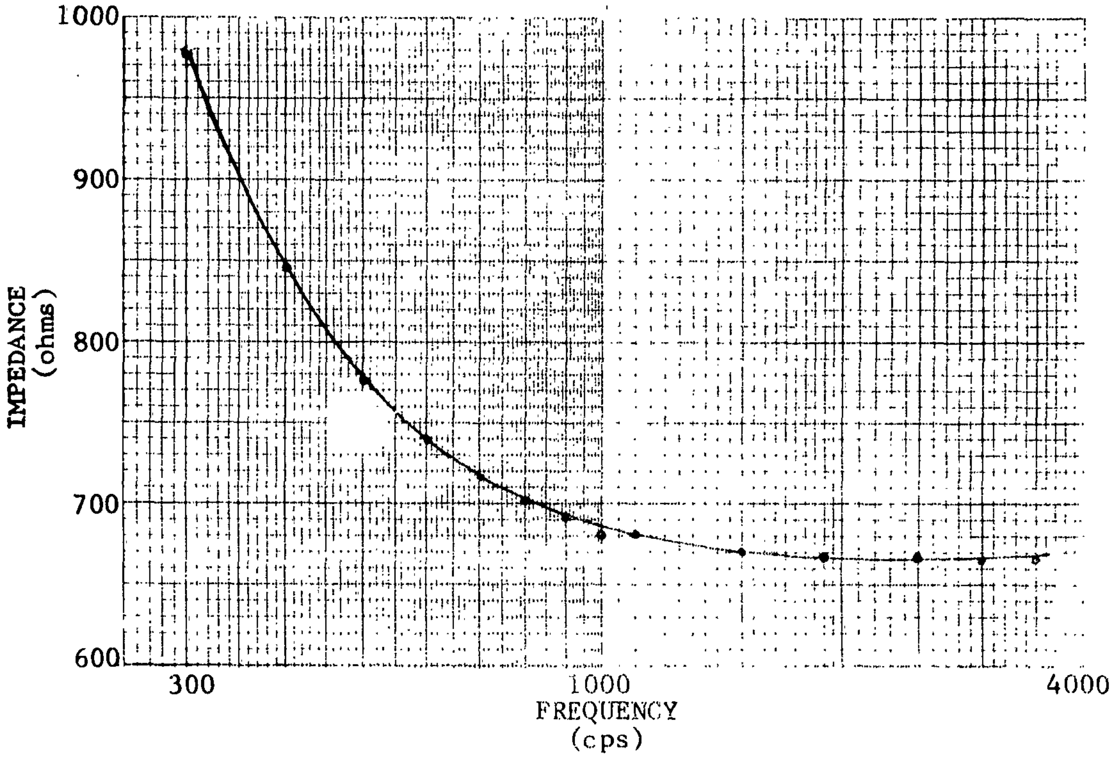


FIGURE B-156

INPUT-OUTPUT IMPEDANCE
AN/TTC-7 TRUNK CIRCUITS

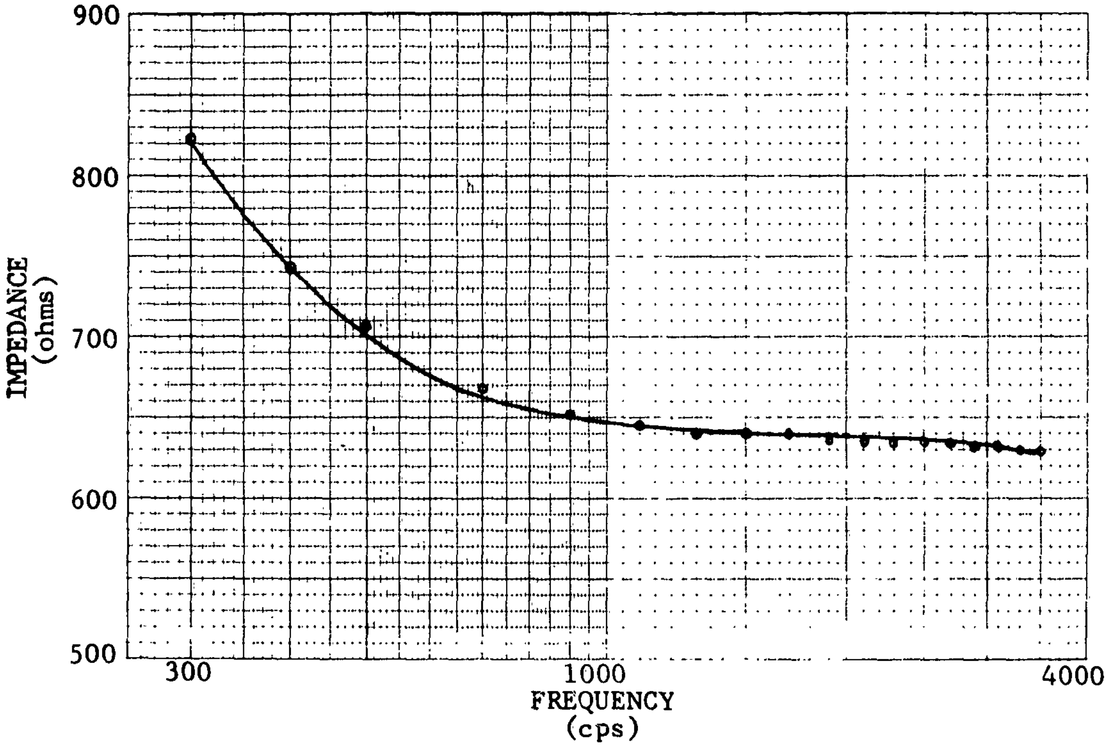


FIGURE B-157

INPUT-OUTPUT IMPEDANCE
AN/TTC-7 LINE CIRCUITS

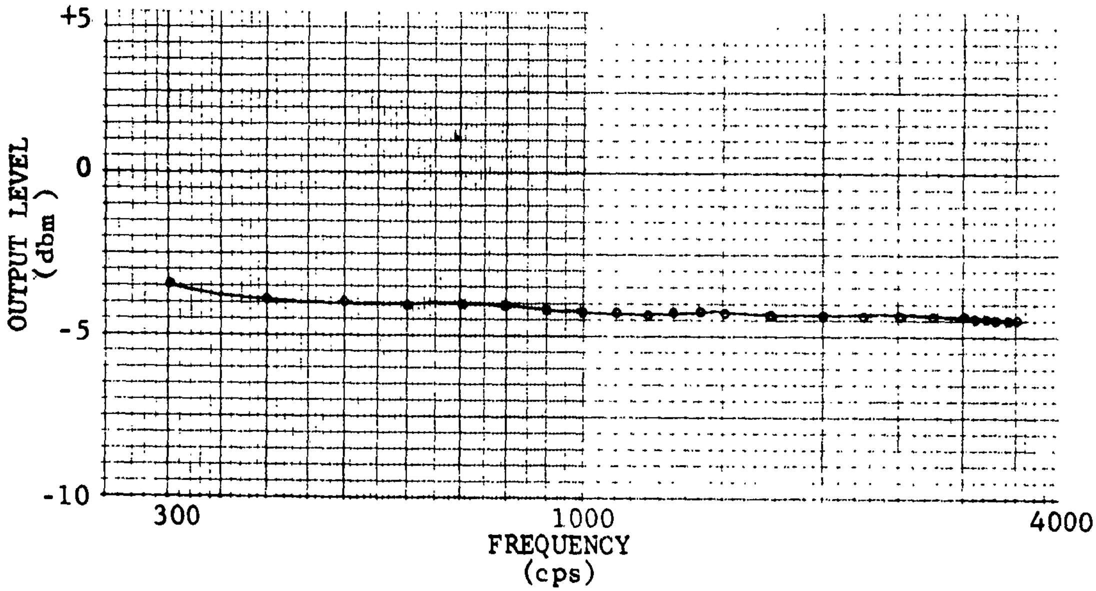


FIGURE B-158

FREQUENCY RESPONSE - AN/TTC-7
Input Level -4 dbm

separated by 200 cps and producing a total signal level of -4 dbm, were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$) cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$) and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distortion products falling within the equipment passband were measured for each frequency pair as shown in Figure B-159. The distortion products are seen to be more than 50 db down from the fundamentals.

2.13.5.4 PHASE DISTORTION

The maximum phase shift detected on the various line to line combinations tested on the AN/TTC-7 was found to be only 0.4 degrees throughout the entire 300 to 3500 cps range; therefore, is not plotted.

2.13.5.5 LONGITUDINAL BALANCE

Longitudinal balance measurements were made on twenty randomly selected send lines using randomly selected receive line and circuits. The longitudinal balance between all lines tested and ground was greater than 68 db below the reference input signal level. The longitudinal balance measured on all lines tested is tabulated in Table B-62.

2.13.5.6 Measurements were made to determine crosstalk, noise and harmonic distortion of the AN/TTC-7. The results obtained in these tests were below the instrumented accuracy of test equipment.

2.14 TEST OF AN/TCC-3 TELEPHONE CARRIER SYSTEM

2.14.1 GENERAL DESCRIPTION

The AN/TCC-3 telephone carrier system utilizes TCC-3 terminals, AN/TCC-5 repeaters with CX-1065 cable or radio links such as the AN/TRC-24, 35 or 36 systems. The cable system has a usable range of 25 miles when no repeaters are used. When the TCC-5 repeater terminal is used the cable range is extended to 100 miles.

2.14.2 OPERATIONAL DESCRIPTION

The system transmits four channels of voice information plus one channel of order wire used for maintenance and administration. The TCC-3 system may be used for transmission and reception of special service broadband information by combining the four channels. Spiral four cable or radio links are used for the interconnection of the system.

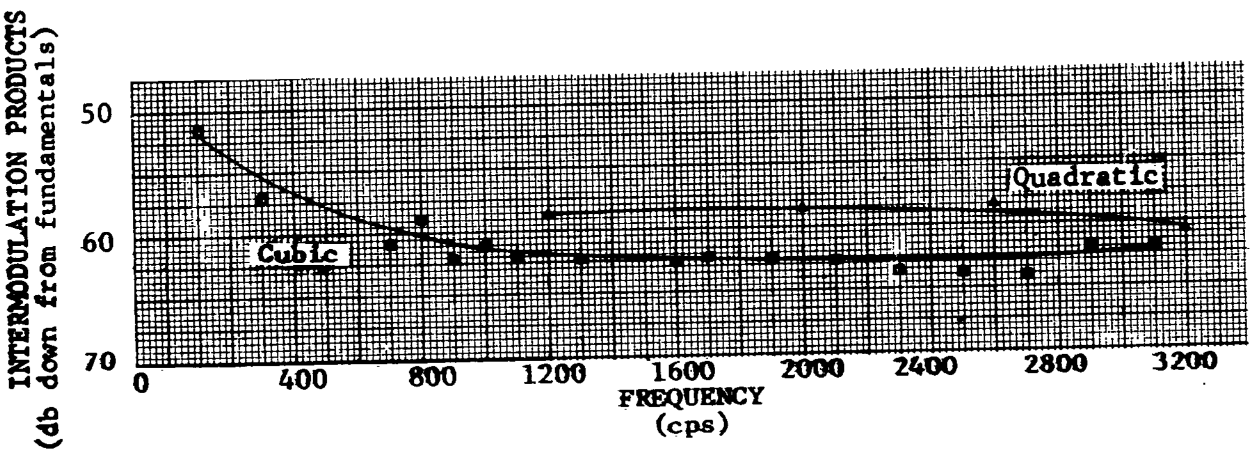


FIGURE B-159

INTERMODULATION DISTORTION - AN/TTC-7
Input Level -4 dbm (total)

TABLE B-62

LONGITUDINAL BALANCE - AN/TTC-7

SEND LINE	RECEIVE LINE	CORD CIRCUIT	LONGITUDINAL BALANCE (db below reference level)
25	95	3	79.1
39	23	12	79.1
78	51	11	68.8
66	78	14	73.4
97	80	10	82.2
100	74	7	79.2
66	25	13	72.5
76	91	9	82.2
86	32	6	82.2
1	49	1	75.2
68	36	4	72.7
45	59	15	68.9
2	28	8	80.2
42	92	2	76.2
64	73	3	68.2
27	62	11	71.6
47	67	10	68.4
60	84	13	73.2
96	53	9	82.2
13	69	1	85.2
		AVERAGE	76.5

2.14.3 TECHNICAL DESCRIPTION

The AN/TCC-3 system accepts voice frequencies between 300 and 3500 cps. A modulator translates the voice frequencies into lower sidebands of four carriers in the eight to twenty kilocycle band. The four channels each have a bandwidth of four kilocycles. Demodulator circuits convert the sideband information back into voice frequency voice channels. A special service circuit is provided which allows the four channels to be combined to form one broadband channel. An order wire circuit having a bandwidth of from 300 to 3500 cps is provided for system maintenance and administration.

The published specifications of the AN/TCC-3 repeater system are as follows:

Range	
System	25 miles
With TCC-5 repeater	100 miles
Message Channels	
Number	4
Frequency Band	300-3500 cps
Impedance	600 ohms
Levels (reference 0 dbm)	
Input - 2 wire	0 dbm
Output - 2 wire	-3 dbm
Input - 4 wire	-4 dbm
Output - 4 wire	+1 dbm
Noise	32 dba
Crosstalk - far end loss	50 db
near end loss	25 db
Order wire signal frequency	1600 cps
System alarm signal frequency	4000 cps

2.14.4 TEST RESULTS

2.14.4.1 INPUT IMPEDANCE

Input impedance measurements were made on all four channels of the AN/TCC-3 carrier equipment. A plot of the arithmetic mean of input impedance versus frequency is shown in Figure B-160. The input impedance varied from a minimum of 600 ohms at 300 cps to a maximum of 670 ohms at 2000 cps.

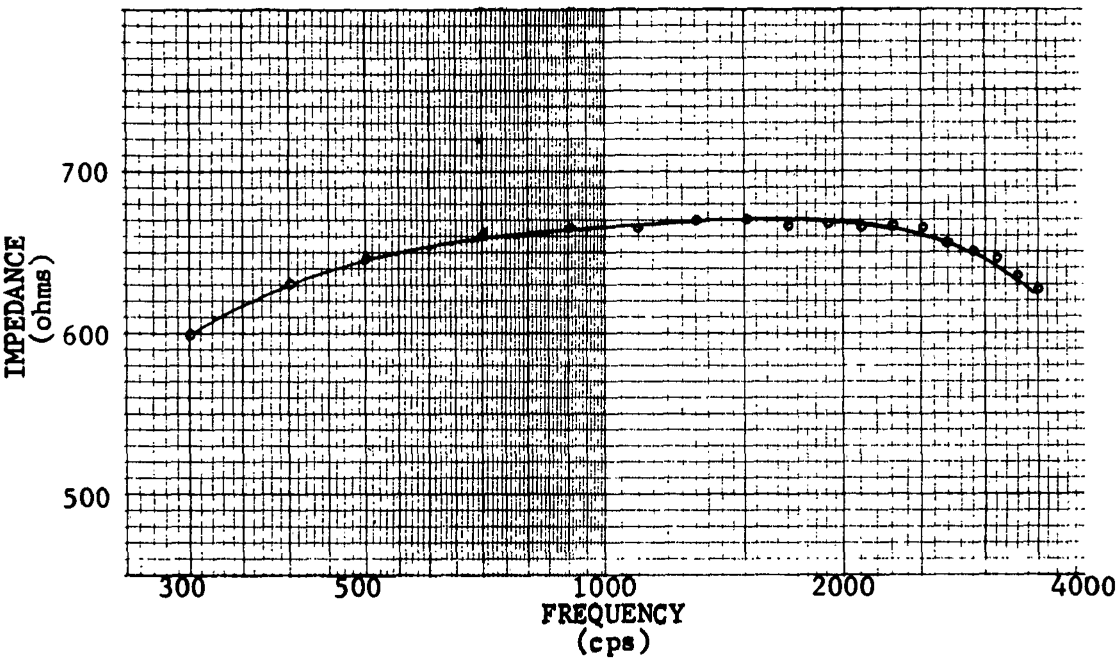


FIGURE B-160

INPUT IMPEDANCE - AN/TCC-3

2.14.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on all four channels of the AN/TCC-3 carrier equipment and a plot of the arithmetic mean versus frequency is shown in Figure B-161. The output impedance varied from a minimum of 525 ohms at 6000 cps to a maximum of 635 ohms at 300 cps.

2.14.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on the four carrier channels of the AN/TCC-3 using an input signal of 0 dbm. A plot of the frequency response of the four channels averaged is shown in Figure B-162. The response was flat within $\pm$ 01.0 db from 300 to 3500 cps. The gain at 1000 cps was +3.5 db.

2.14.4.4 CROSSTALK LOSS

Measurements were made of near end and far end crosstalk loss on eight AN/TCC-3 carrier channel combinations. Figure B-163 is a plot of the arithmetic average of the crosstalk measured at the disturbed channel, using an input to the disturbing channel of 0 dbm. The crosstalk loss on all disturbed channels was found to be greater than -74.0 db down from the disturbing channel.

2.14.4.5 HARMONIC DISTORTION

Measurements were made of all four AN/TCC-3 carrier channels to determine the per cent of harmonic distortion. These measurements showed the third harmonic to be the main source of distortion. A plot of the arithmetic mean of all lines averaged is shown in Figure B-164.

2.14.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on all four channels of the AN/TCC-3. A pair of fundamental frequencies (f_1 and f_2) separated by 200 cps and producing a total signal level of 0 dbm were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$) cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$) and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distortion products falling within the equipment passband were measured for each frequency pair as shown in Figure B-165. The distortion products are seen to be more than 32 db down from the fundamentals.

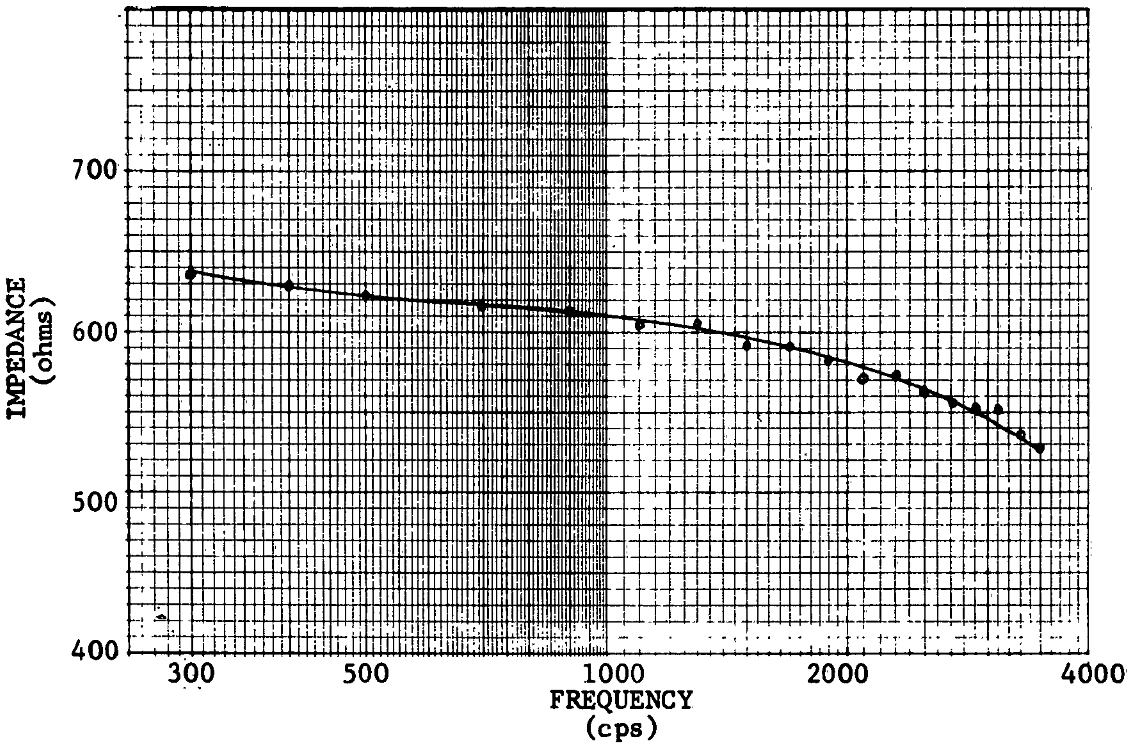


FIGURE B-161

OUTPUT IMPEDANCE - AN/TCC-3

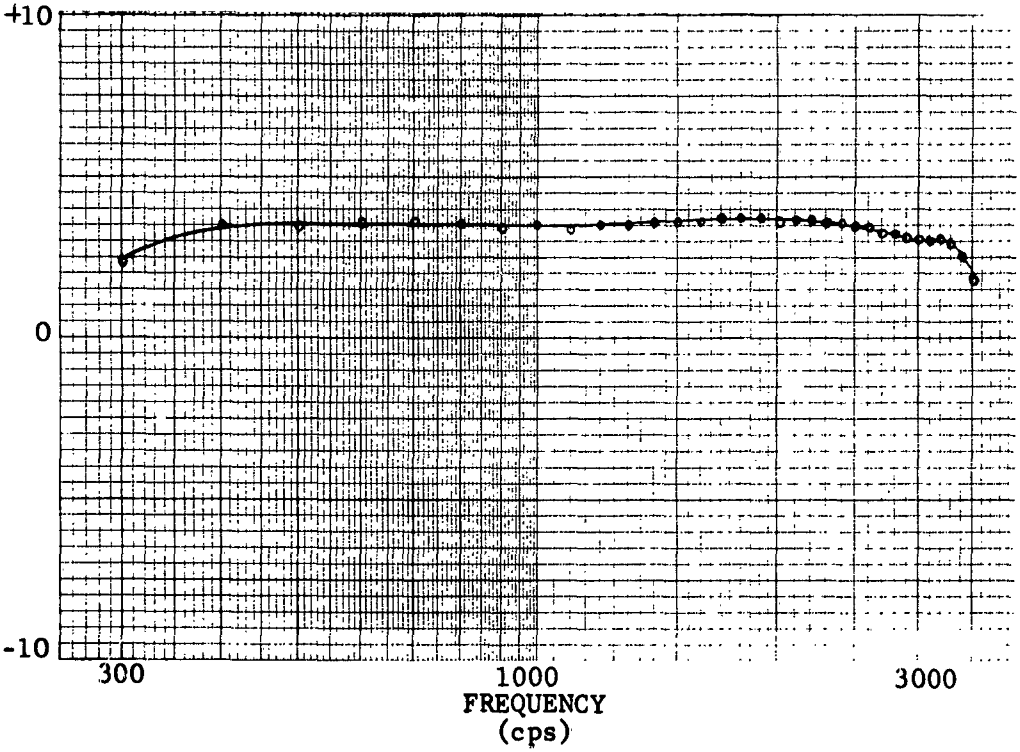


FIGURE B-162

FREQUENCY RESPONSE - AN/TCC-3
Input Level 0 dbm

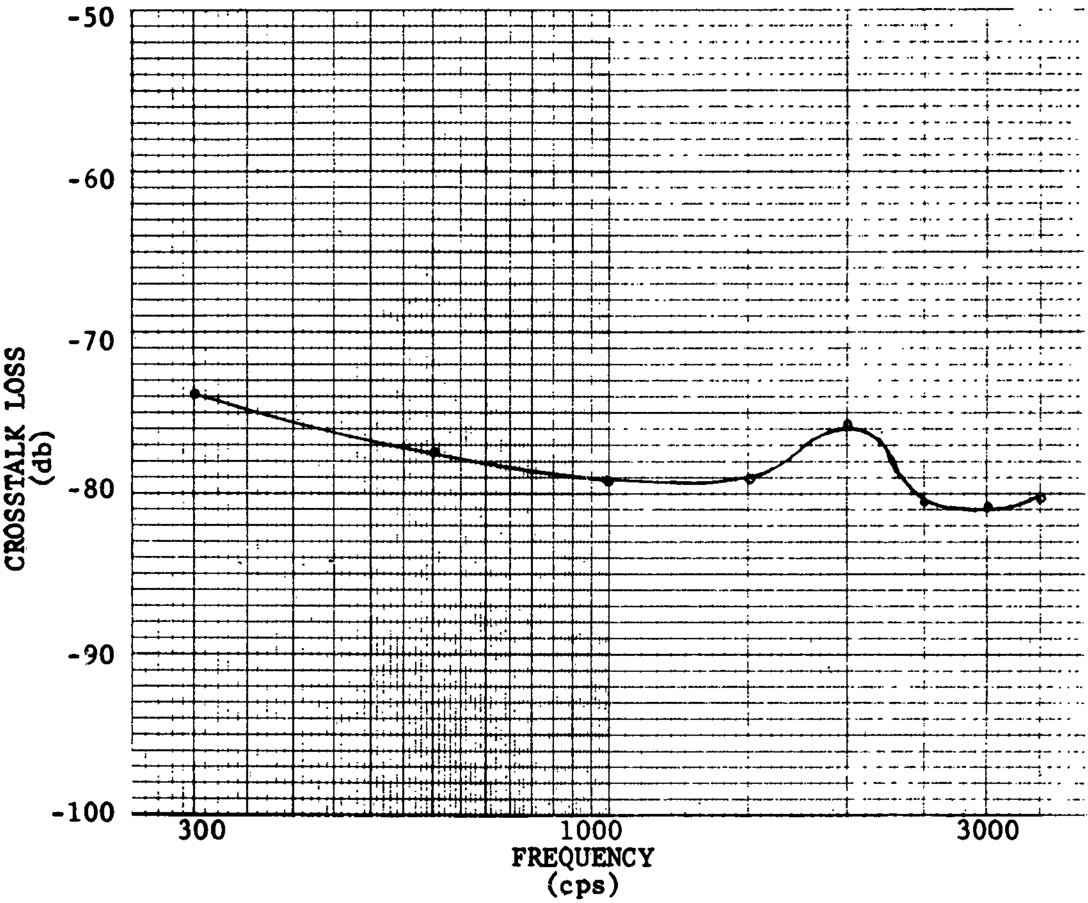


FIGURE B-163

CROSSTALK LOSS - AN/TCC-3
Input Level 0 dbm

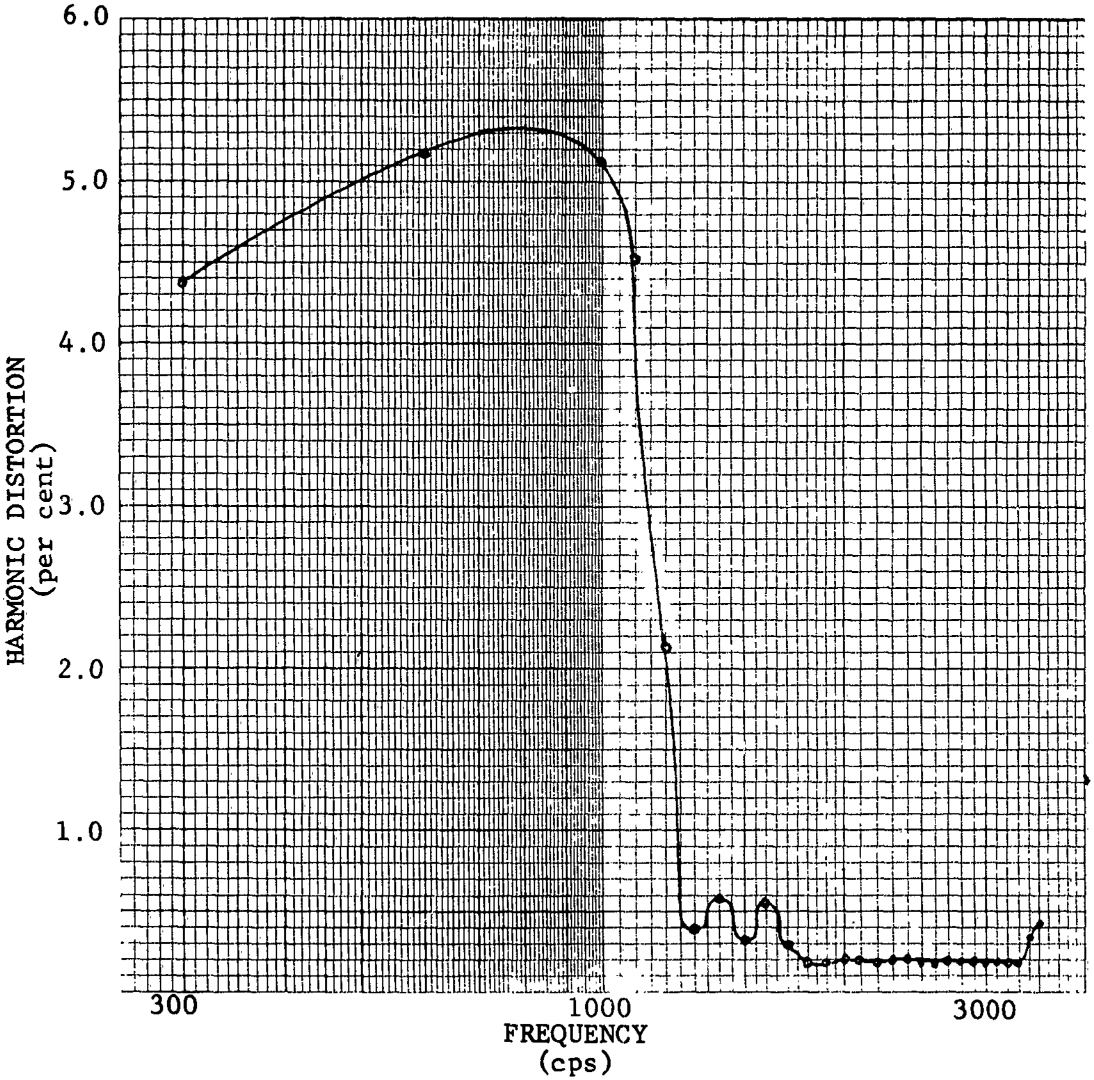


FIGURE B-164

HARMONIC DISTORTION - AN/TCC-3
Input Level 0 dbm

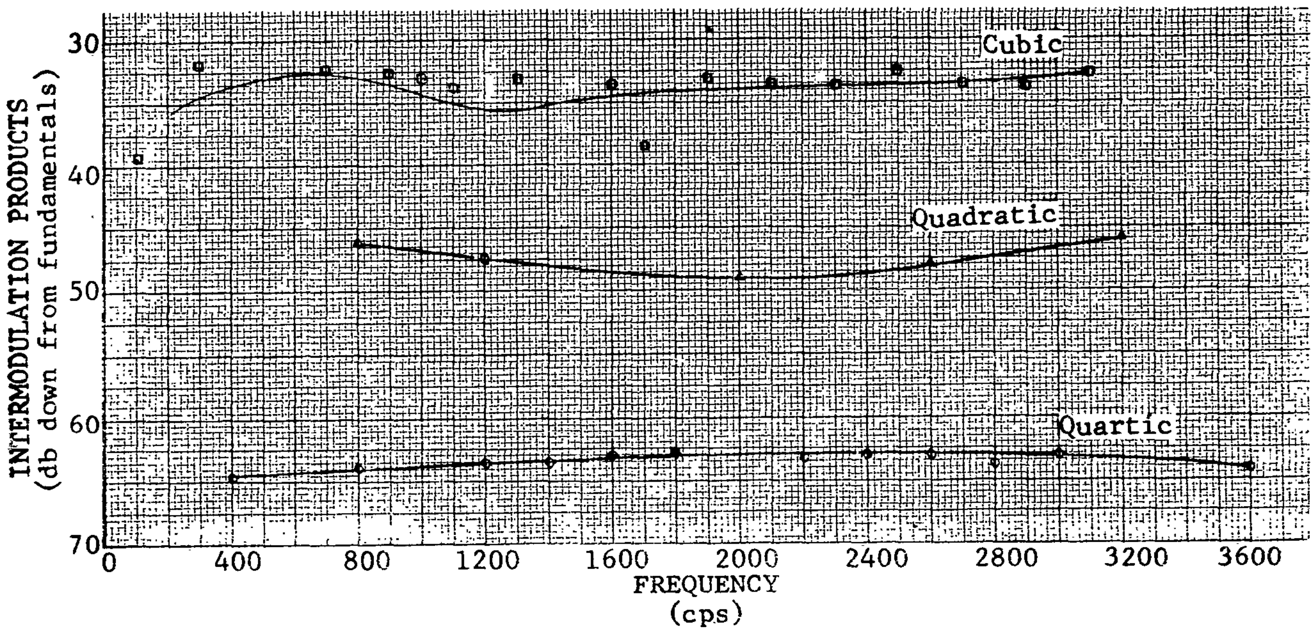


FIGURE B-165

INTERMODULATION DISTORTION - AN/TCC-3
Input Level 0 dbm (total)

2.14.4.7 LIMITING

Limiting was measured on all four carrier channels of the AN/TCC-3. Figure B-166 is a plot of the arithmetic mean of the limiting action of all channels.

2.14.4.8 NOISE

Measurements on all four channels of the AN/TCC-3 showed the noise levels to be below 17 dba, the sensitivity of the test instrumentation.

2.15 TEST OF AN/TCC-7 TELEPHONE CARRIER SYSTEM

2.15.1 GENERAL DESCRIPTION OF SYSTEM

The AN/TCC-7 telephone carrier system utilizes AN/TCC-7 terminals, AN/TCC-8 repeaters, AN/TCC-11 repeaters and interconnecting CX-1065 cable or radio links (AN/TRC-24) to form a telephone carrier communications system with a usable range of from 200 to 300 miles.

2.15.2 OPERATIONAL DESCRIPTION

The system provides twelve channels of voice information plus one order wire channel. Some or all of the channels may be combined to form special wide band frequency channels for data transmission. Spiral four cable and radio links are used for interconnection of the system. When cables are used as the transmission medium the TCC-11, an unattended repeater powered by 600 volt dc phantomed on the cable, must be used every five miles. In addition, TCC-8 repeaters (attended) must be placed every forty miles. When radio links are used, the radio must be fed by and in turn feed into a TCC-8 or a TCC-7 terminal.

The TCC-7 carrier system is used to make up trunks from switchboard to switchboard wherever there is a need for extended range connections. A number of TCC-7 systems may be connected in tandem or in combination with other systems.

2.15.3 TECHNICAL DESCRIPTION

Modulator circuits translate the incoming voice frequencies into lower sidebands generated around carriers ranging from twelve to sixty kilocycles. There are twelve channels each with a bandwidth of four

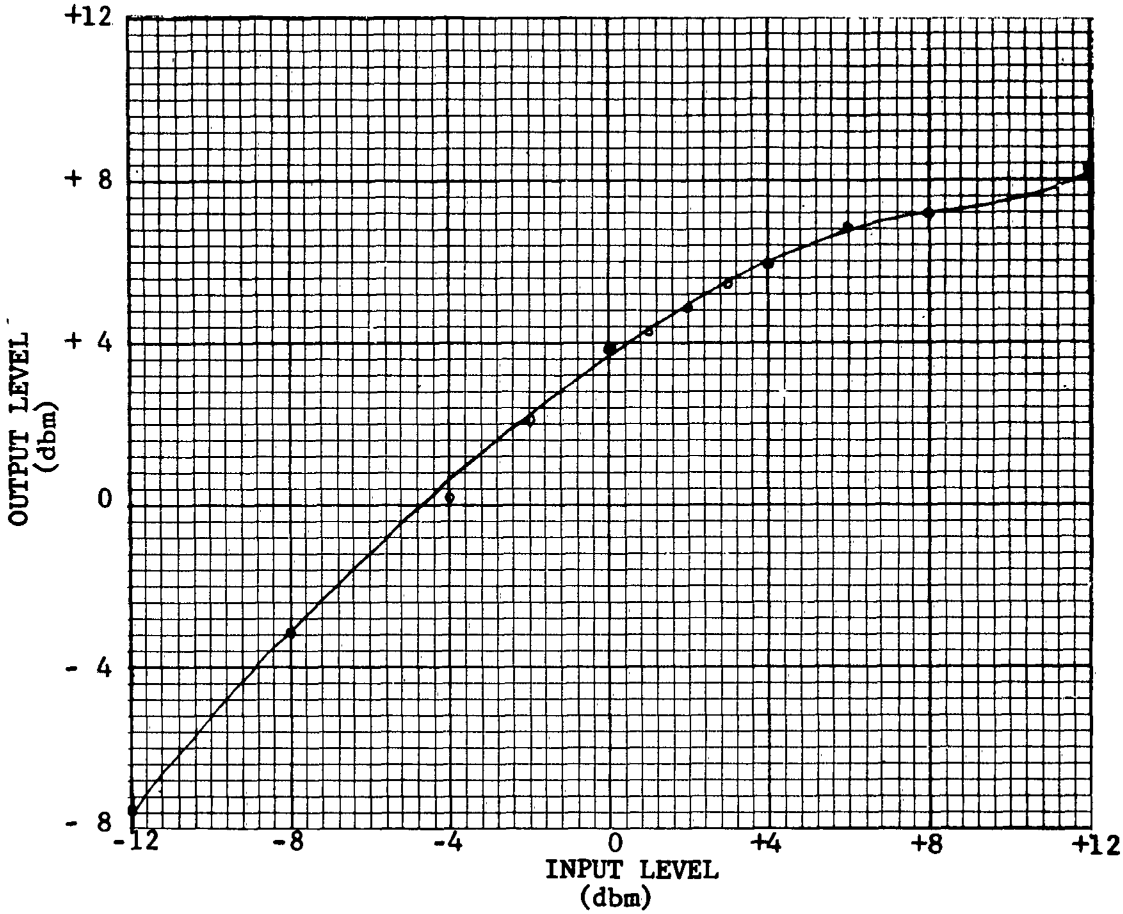


FIGURE B-166

LIMITING - AN/TCC-3

kilocycles. In addition, there is an order wire channel and a sixty eight kilocycle tone. This tone is transmitted continuously for automatic regulation to compensate for cable losses. Demodulator circuits convert the sideband information back into low frequency voice channels.

Special service circuits permit broadband signals to be transmitted through the system. Sixteen kilocycle and forty eight kilocycle bandwidths can be accomodated by combining the low frequency channels or in a separate channel from sixty to one hundred and eight kilocycles modulating a one hundred and twenty kilocycle carrier.

Amplifiers, regulators and equalizers compensate for cable and other losses that occur with frequency and temperature variations.

The order wire circuit has talking and ringing facilities for use in system maintenance and administration.

Dc supplies send power down the cable for TCC-11 repeater operation.

Test signals of twelve, twenty eight, or sixty four kilocycles can be introduced into the system by the operator.

The specifications of the AN/TCC-7 repeater system are as follows:

Range				
System		200 miles		
Attended repeater section		40 miles		
Unattended repeater		5-3/4 miles		
Message Channels				
Number		12		
Frequency Band		300-3500 cps		
Impedance		600 ohms		
Levels				
Two wire operation		0 db input -3 db output		
Four wire operation		-4 db input +1 db output		
Special Service Channels				
Freq.Band (kc)	No.Channels	Input	Output	Impedance
40-20	3	0 db	0 db	600 ohm
12-60	1	0 db	-2 db	135 ohm
60-108	1	0 db	-5 db	135 ohm
Pilot Frequency		68 KC at 0 dbm		
Order Wire				
Frequency Range		300-1700 cps		
Signal Frequency		1600 cps		
Transmitting Level to Cable		20 db max		
Transmitting Level to Radio		10 db max		

2.15.4 TEST RESULTS AN/TCC-7

2.15.4.1 INPUT IMPEDANCE

Input impedance measurements were made on all twelve channels of the AN/TCC-7. A plot of the most probable mean of the input impedance versus frequency and the range defining the limit of excursion of sample means with a 95 per cent confidence level is shown in Figure B-167. The input impedance varied from a minimum of 620 ohms at 300 cps to a maximum of 670 ohms at 1100 cps.

2.15.4.2 OUTPUT IMPEDANCE

Output impedance measurements were made on all twelve channels of the AN/TCC-7 carrier equipment. A plot of the most probable mean of the output impedance versus frequency and the range defining the limit of excursion of sample means with a 95 per cent confidence level is shown in Figure B-168. The output impedance varied from a minimum of 550 ohms at 3500 cps to a maximum of 675 ohms at 300 cps.

2.15.4.3 FREQUENCY RESPONSE

Frequency response measurements were made on eight randomly selected carrier channels of the AN/TCC-7 using an input signal of 0 dbm. A plot of the frequency response is shown in Figure B-169.

2.15.4.4 CROSSTALK LOSS

The crosstalk loss measured on randomly selected carrier channels of the AN/TCC-7 was found to be greater than 60 db down from the disturbing channel, using an input level of 0 dbm and therefore was not plotted.

2.15.4.5 HARMONIC DISTORTION

Measurements were made on randomly selected carrier channels of the AN/TCC-7 to determine the per cent total harmonic distortion. These measurements showed the third harmonic to be the main source of distortion. A plot of the arithmetic mean of all lines averaged is shown in Figure B-170.

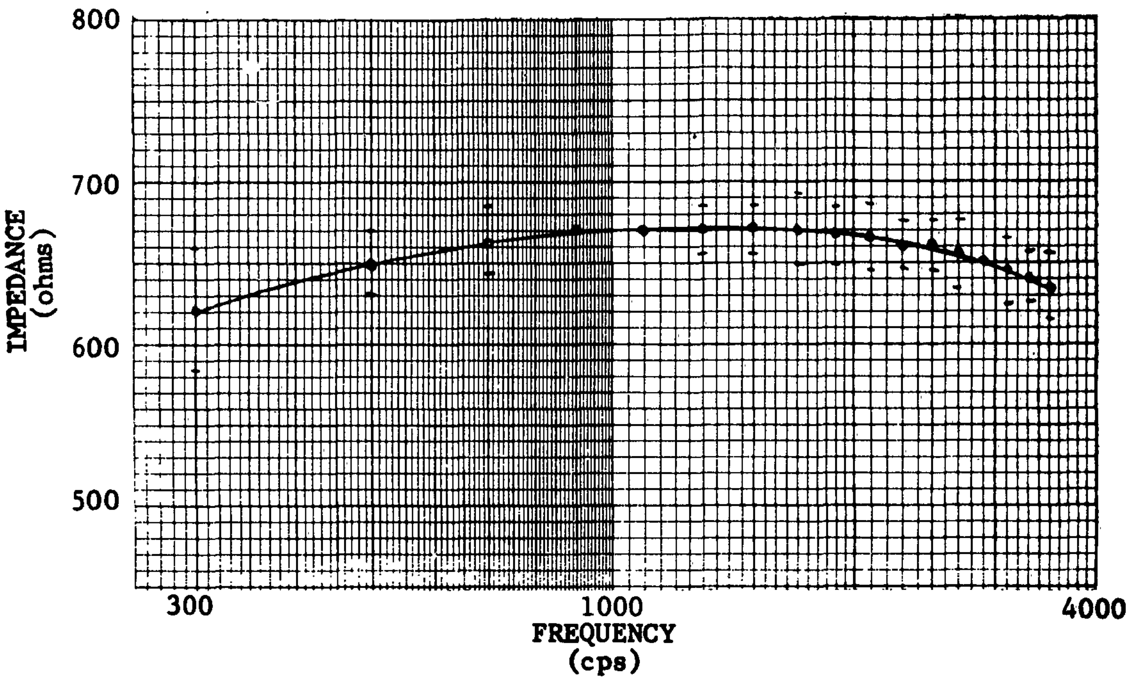


FIGURE B-167

INPUT IMPEDANCE - AN/TCC-7

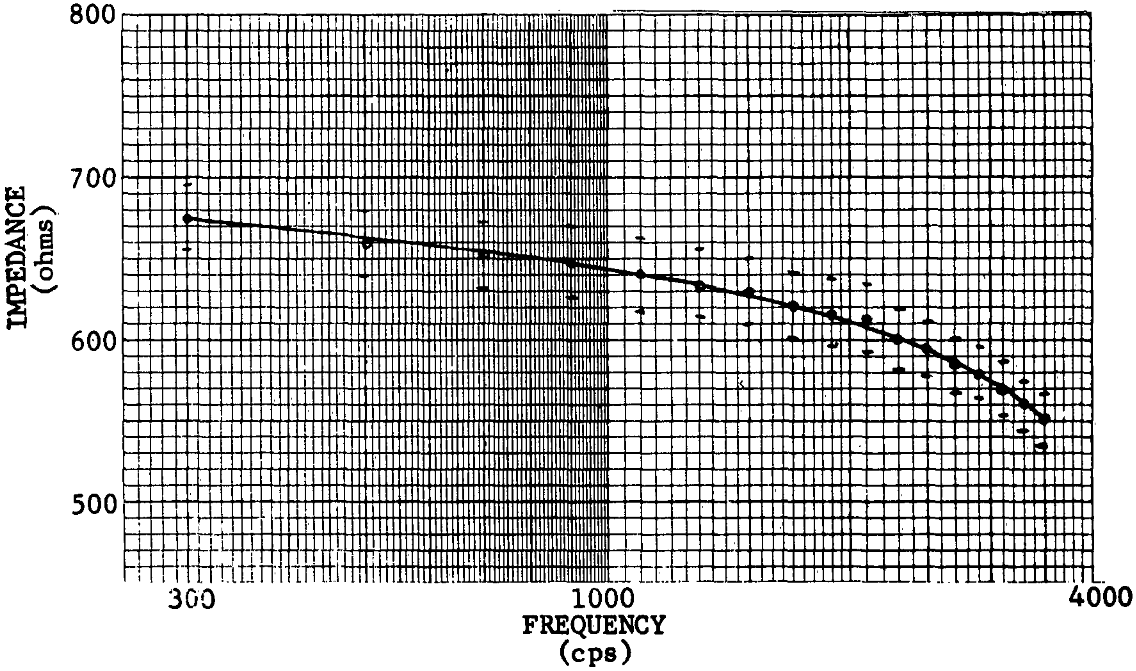


FIGURE B-168

OUTPUT IMPEDANCE - AN/TCC-7

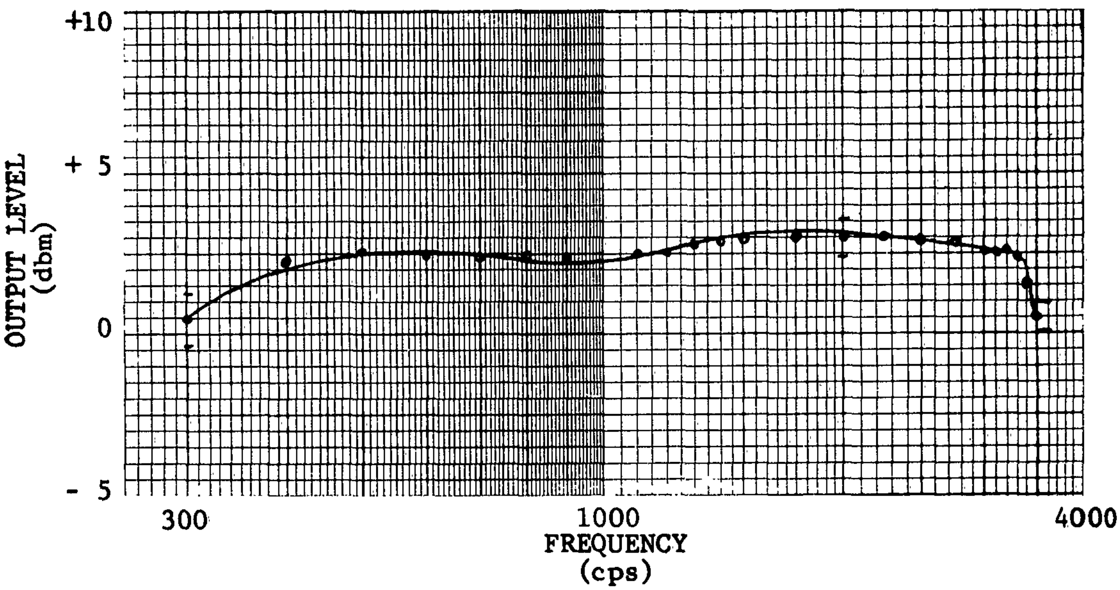


FIGURE B-169

FREQUENCY RESPONSE - AN/TCC-7
Input Level 0 dbm

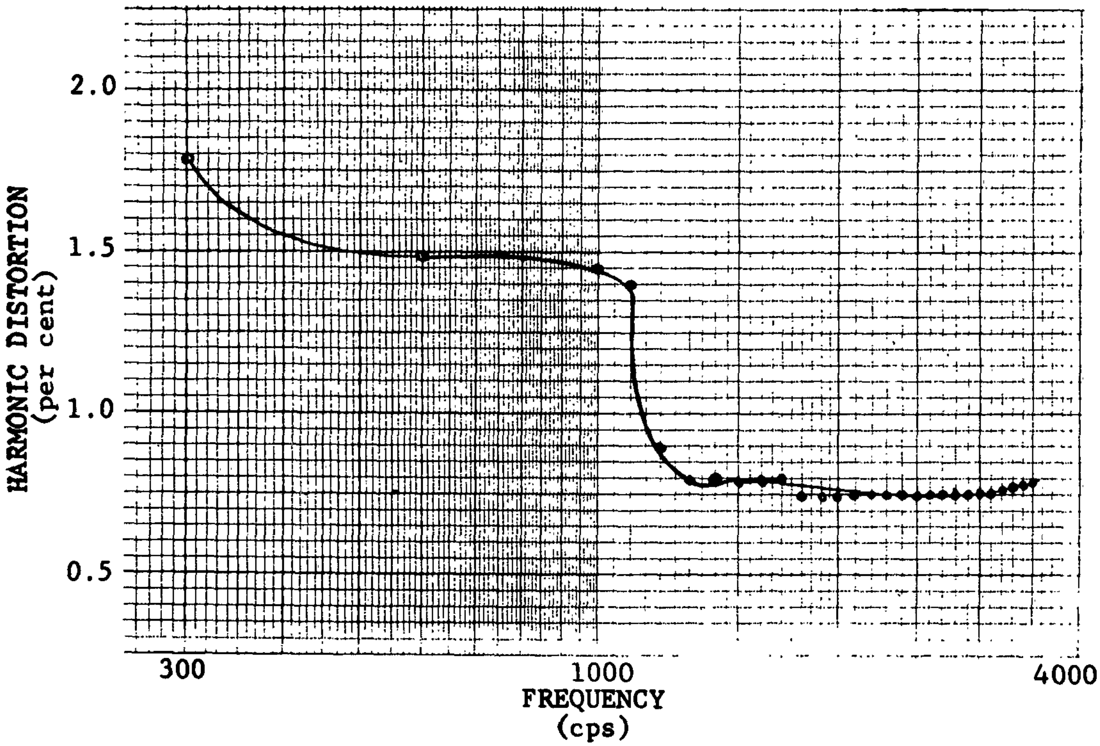


FIGURE B-170

HARMONIC DISTORTION - AN/TCC-7
Input Level 0 dbm

2.15.4.6 INTERMODULATION DISTORTION

Intermodulation distortion products were measured on random carrier channels of the AN/TCC-7. A pair of fundamental frequencies (f_1 and f_2), separated by 200 cps and producing a total signal level of 0 dbm, were used. The quadratic ($f_2 - f_1$; $f_2 + f_1$) cubic ($2f_2 + f_1$; $2f_2 - f_1$; $2f_1 + f_2$; $2f_1 - f_2$) and quartic ($3f_1 - f_2$; $3f_2 - f_1$; $3f_1 + f_2$; $3f_2 + f_1$; $2f_1 + 2f_2$) distion products falling within the equipment passband were measured for each frequency pair as shown in Figure B-171. The distortion products are seen to be more than 30 db down from the fundamentals.

2.15.4.7 PHASE DISTORTION

Envelope delay time was determined on randomly selected carrier channels of the AN/TCC-7. A plot of the arithmetic mean of delay time versus frequency is shown in Figure B-172.

2.15.4.8 LIMITING

Limiting action was measured on randomly selected carrier channels of the AN/TCC-7. A plot of the arithmetic mean of input versus output of the sampled channels is shown in Figure B-173.

2.15.4.9 NOISE

Noise measurements were made on all twelve channels of the AN/TCC-7. On all channels sampled the noise level was lower than 27 dba.

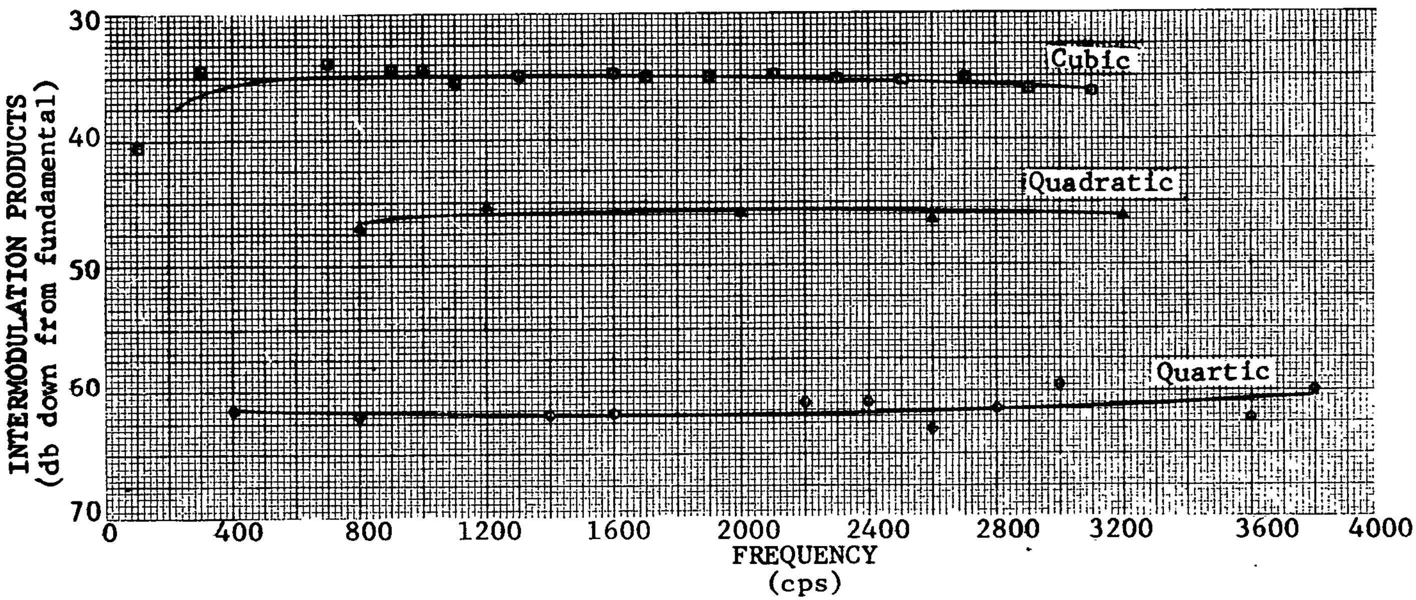


FIGURE B-171

INTERMODULATION DISTORTION - AN/TCC-7
Input Level 0 dbm (total)

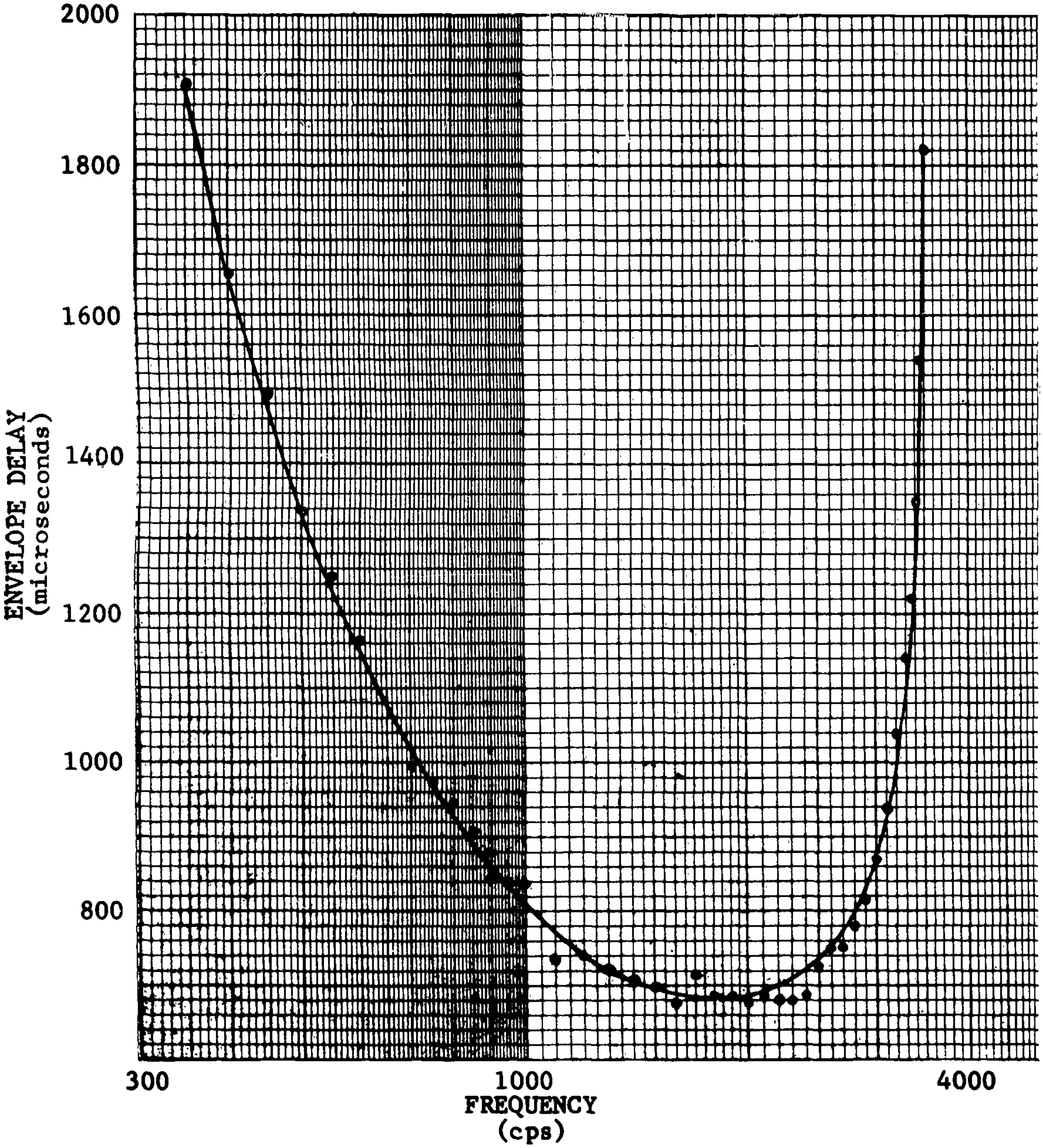


FIGURE B-172

ENVELOPE DELAY - AN/TCC-7
Input Level 0 dbm

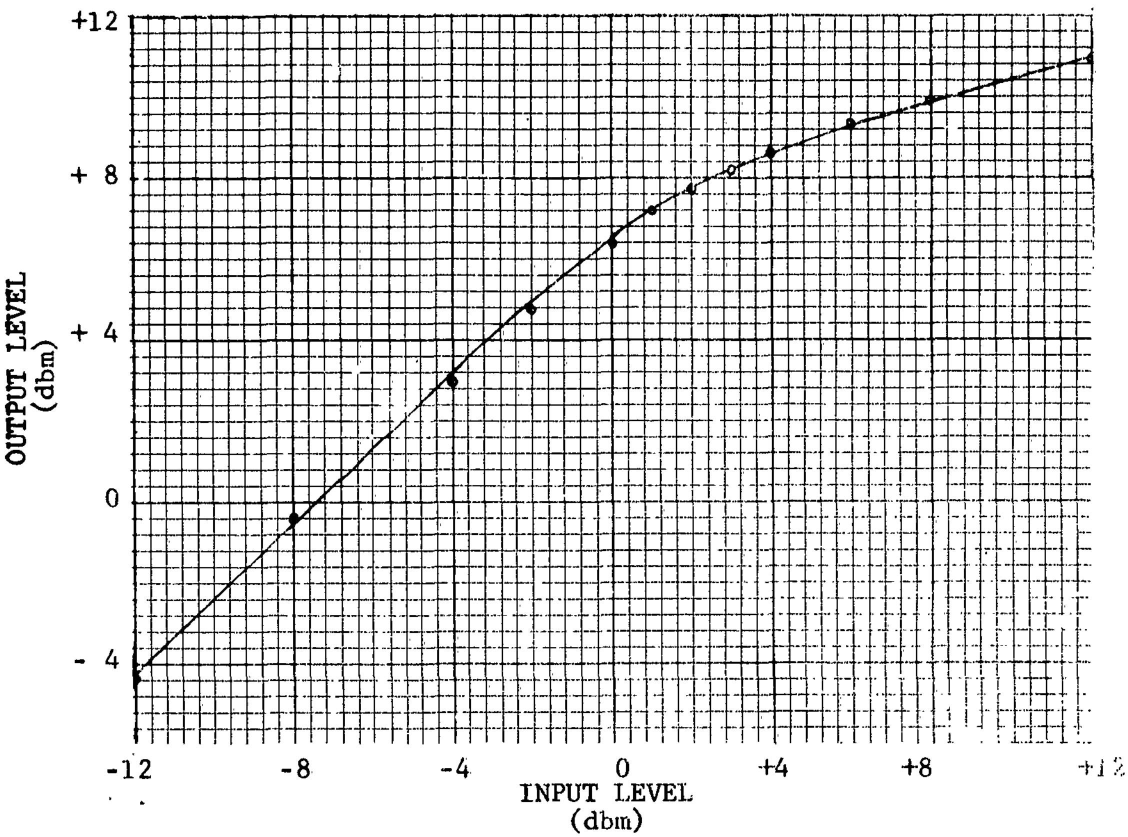


FIGURE B-173

LIMITING - AN/TCC-7

3.0 INTEROPERATIONAL AND COMPATIBILITY TEST RESULTS

This section presents the results of testing the automatic electronic switching equipments in the system configurations defined in the Test Plan, Volume II. The apology must be made that the data presented herein is not as complete as could be desired; the justification for this being the lateness of delivery and maintenance difficulties on the new prototype equipments and the failure of several critical items of test equipment (Maxson Phasemeter, Western Electric Audio Wave Analyzer). The efforts on the tests were thus concentrated to broadly bracket the system performance capability of the automatic switching centrals.

3.1 INTEROPERATIONAL TEST RESULTS

3.1.1 GENERAL

The Test Plan, Volume II, outlined the requirements for the interoperational tests which consisted basically of frequency response, harmonic distortion, phase distortion, noise and signal to noise measurements. These were to be taken on six increasingly complex configurations as illustrated in Figures A-5 through A-10 of Volume II. The six configurations were, further, to be interconnected by wire, wire carrier and radio carrier transmission media.

3.1.2 TRANSMISSION (TRUNKING) MEDIA CHARACTERISTICS

In determining interoperational capabilities between the automatic electronic switching centrals, it is necessary to isolate the effects of the interconnecting transmission media. The following paragraphs discuss the wire, wire carrier and radio carrier trunking circuits.

3.1.2.1 WIRE ONLY

The solid wire circuits provided for the interoperational tests were the short runs required to interconnect the various switching centrals via the instrumentation control center at the Signal Communication Department Test Facility. The data acquired, in view of the very short wire runs necessary to interconnect, represents the back to back connection of the switching centrals, and, as such, forms the basis for comparison for the further tests over extended lengths of wire and over wire and radio carrier systems.

3.1.2.2 WIRE CARRIER

The wire carrier system used for these tests consisted of 100 miles of CX-1065 (spiral four) field cable, 15 AN/TCC-11 repeaters, 2 AN/TCC-8 repeaters and 2 AN/TCC-7 telephone carrier terminals. Mileage intervals for single channel operation from 5-3/4 to 100 miles in 5-3/4 mile increments were available for use in this test. The interoperational and compatibility tests were all run using the full 100 mile capability of the system. Greater mileage intervals were obtained by looping back and forth through the 12 channels of the AN/TCC-7 carrier system.

Figure B-174 shows the frequency response curves for 0, 11.5 miles, 100 miles and 700 miles operation of the AN/TCC-7 carrier system. In general, the response is flat from 400 to 3000 cps. The differences evidenced in insertion loss is attributable to the calibration of the equipment or to major system losses. In the 0 mile curve the AN/TCC-7 was adjusted according to standard 4 wire system procedures (5 db gain). The other curves were taken with a no-loss loop calibration (at -4 dbm). The lower level of the 700 mile curve was due to overall cable losses which were not fully compensated for in the system amplifiers.

Figure B-175 shows the harmonic distortion curves for 0, 11.5, 100 and 700 miles operation of the AN/TCC-7 carrier systems. The single path (0, 11.5, 100 mile) curves display normal (below 3 per cent) total harmonic distortion. The high distortion evidenced over the 700 mile path is due to high cable losses, and to crosstalk generated within the 7 paralleled channels.

3.1.2.3 RADIO CARRIER

The AN/MRC-69 (AN/TRC-24) radio carrier system was utilized to provide the radio carrier trunks in the interoperational tests. Figures B-176 and B-177 show the plan view of the site locations, and the terrain elevation profiles for radio paths 1 through 4. Time permitted but a cursory check of path quality on the multiple hop radio paths. Receiver AGC was monitored for all configurations, and all radio paths were found to be of good quality.

The circuit quality was checked in detail on path number 1 from the Signal Communications Department Test Area to the remote radio site. Frequency response and distortion were essentially identical to the back

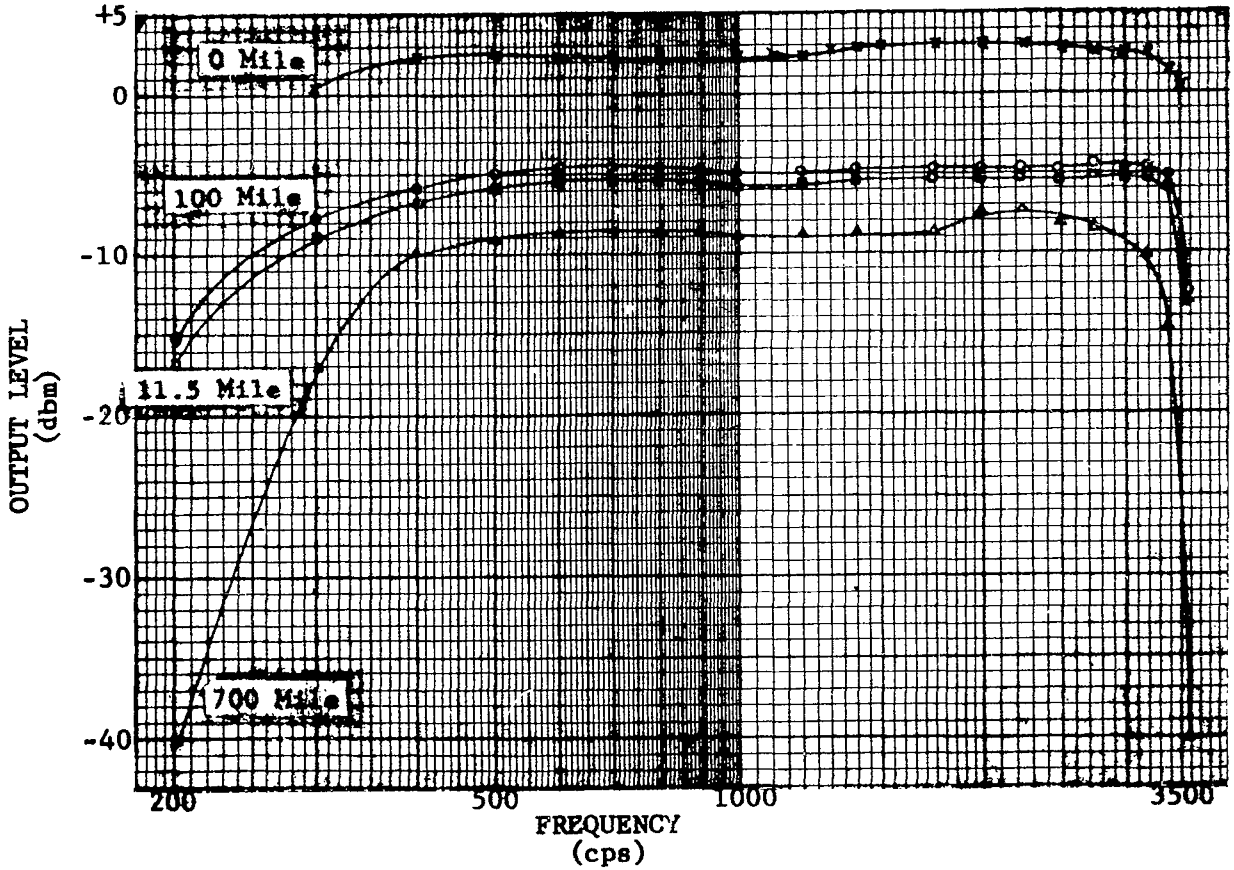


FIGURE B-174

FREQUENCY RESPONSE
AN/TCC-7 WIRE CARRIER SYSTEM
(100 Mile Cable Run - CX-1065)

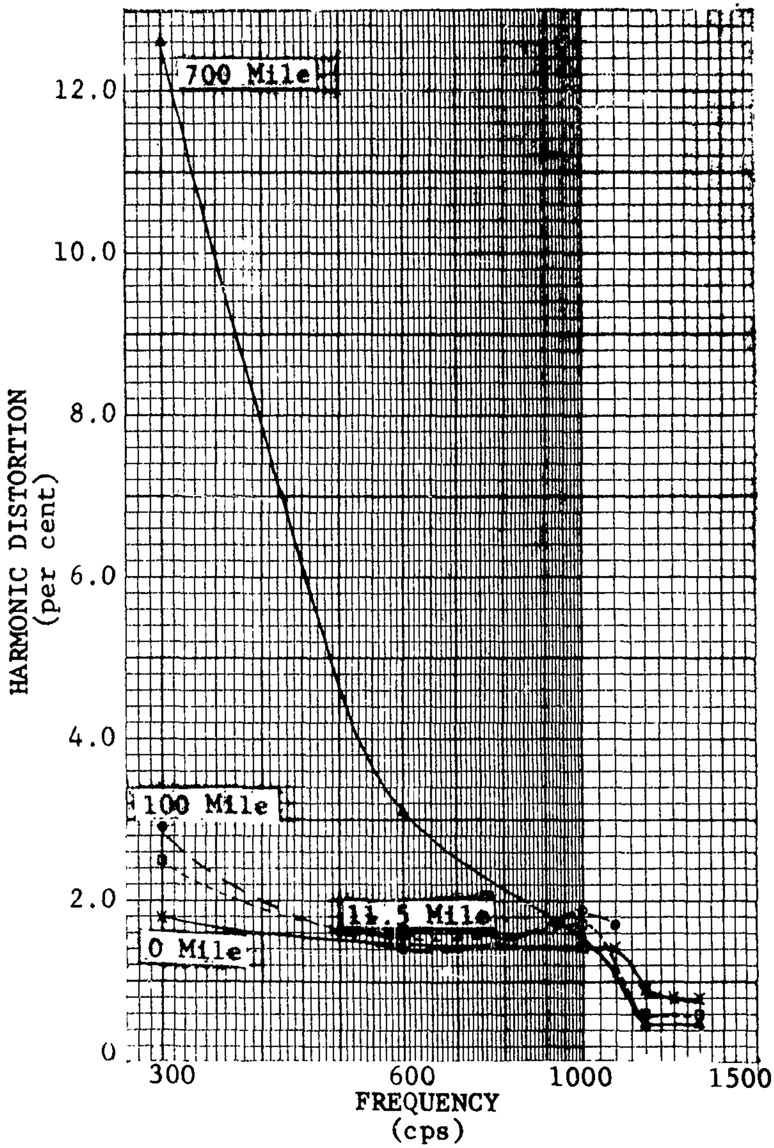


FIGURE B-175

HARMONIC DISTORTION
AN/TCC-7 WIRE CARRIER SYSTEM
(100 Mile Cable Run - CX-1065)

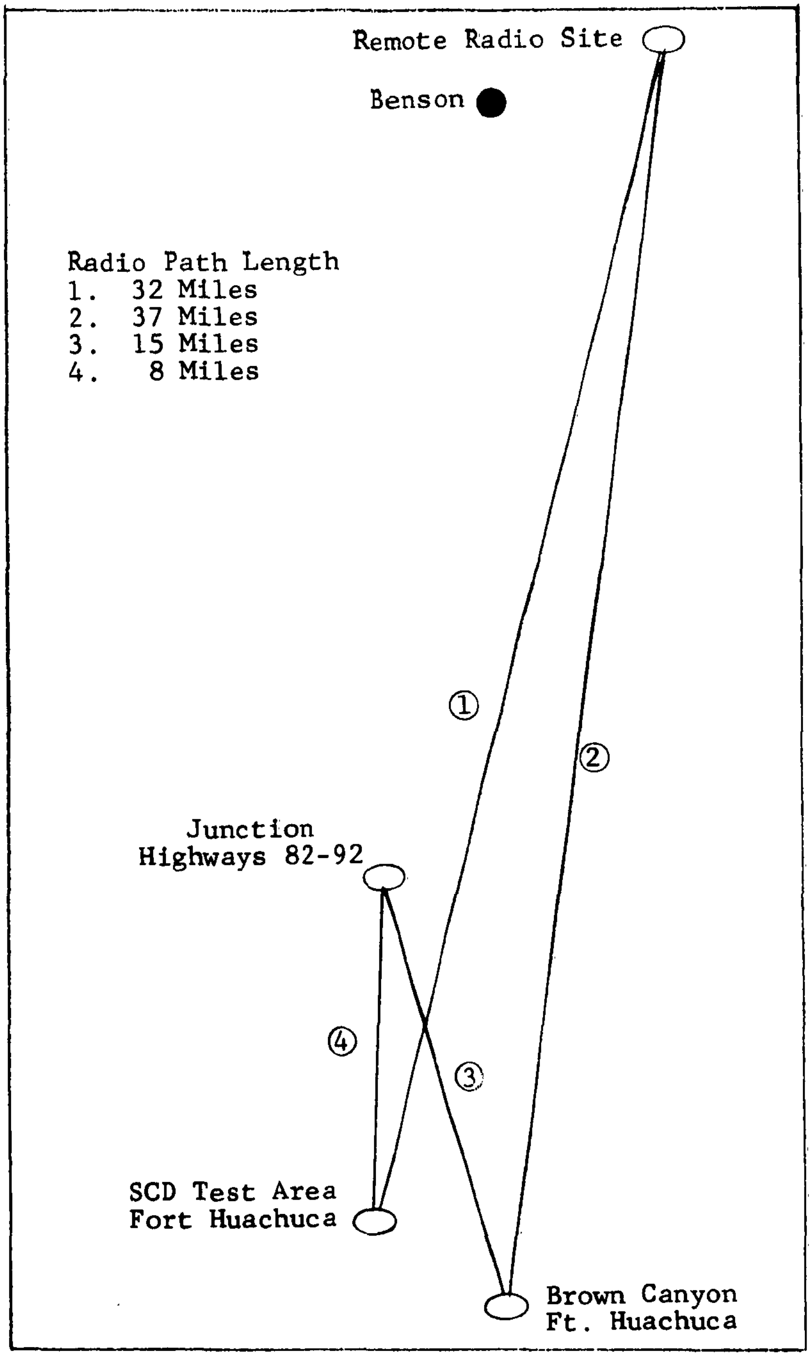


FIGURE B-176

RADIO TEST SITES LOCATIONS
FOR INTEROPERATIONAL/COMPATIBILITY TESTS

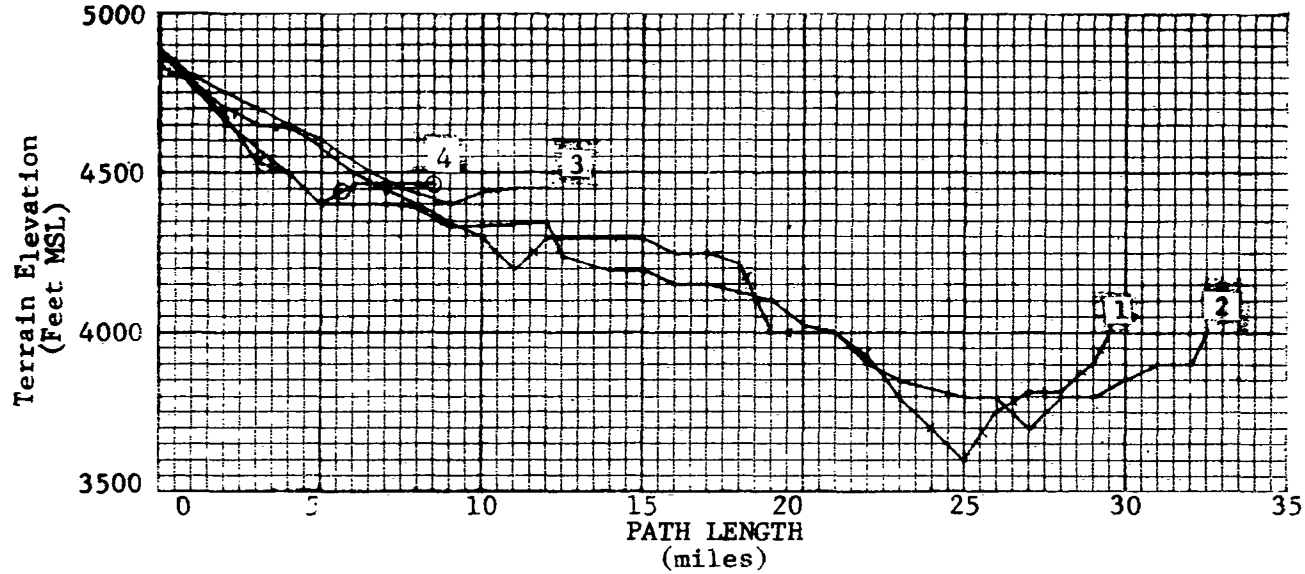


FIGURE B-177

RADIO PATH TERRAIN ELEVATION PROFILES

to back (0 mile) test on the AN/TCC-7 shown in Figures B-174 and B-175.

3.1.3 TEST RESULTS (INTEROPERATIONAL)

Figure B-178 shows the six basic system test configurations reported on in the following paragraphs. Details of each of these configurations are presented in Volume II, Test Plans. The testing involved interconnecting these configurations by wire, wire carrier and radio carrier. A test configuration, labelled 6A, was used to describe a multiple radio site test, in contrast to 6, which involved sending signals back and forth over one path. In collecting data on the systems tests, measurements were taken at all switching central/carrier interfaces. This approach was helpful in explaining anomalies within the plotted overall system results.

3.1.3.1 FREQUENCY RESPONSE

Figures B-179 through B-181 show the frequency response characteristics of the tested system configurations over wire, wire carrier and radio carrier trunks. The response curves on wire for configurations 1, 2 and 6, shown in Figure B-179, could be predicted from the response curves obtained in the basic equipments (Section 2.0). The response curves on wire carrier shown in Figure B-180 are predictable except for the curve of configuration 6 which is unexplainable except for possible effects due to carrier misalignment, observed as an unusual gain through one of the carrier paths at the low frequency end of the spectrum.

The response curves over radio carrier, shown in Figure B-181, is also predictable except for configuration 6A which is also unexplainable. The same AN/TCC-7 carrier terminals were used in this test as in the wire test which also showed unpredictable response.

3.1.3.2 HARMONIC DISTORTION

Figures B-182 through B-184 show the harmonic distortion plots for the three trunking media. The wire interconnect data of Figure B-182 shows the distortion to be under 2.5 per cent for all configurations which agrees with the data obtained on the individual equipments. The wire carrier data of Figure B-183 shows the expected increases as the system becomes more complex. Configuration 6 distortion is higher and more variable than would be expected. The data on this particular test showed an unusually high distortion incremental rise through one of the carrier channels. The radio carrier distortion shown in Figure B-184 is predictable.

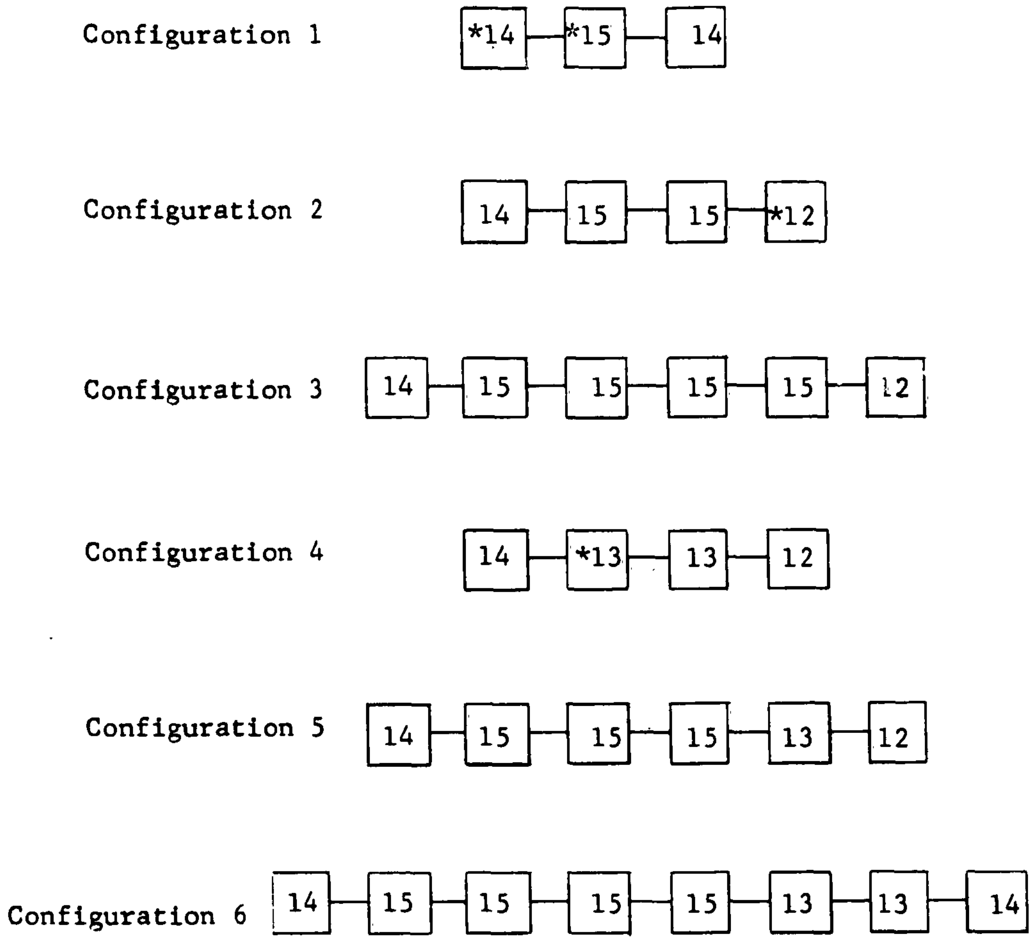


FIGURE B-178

INTEROPERATIONAL TEST CONFIGURATIONS

*Note:

12	AN/TTC-12
13	AN/TTC-13
14	AN/TTC-14
15	AN/TTC-15

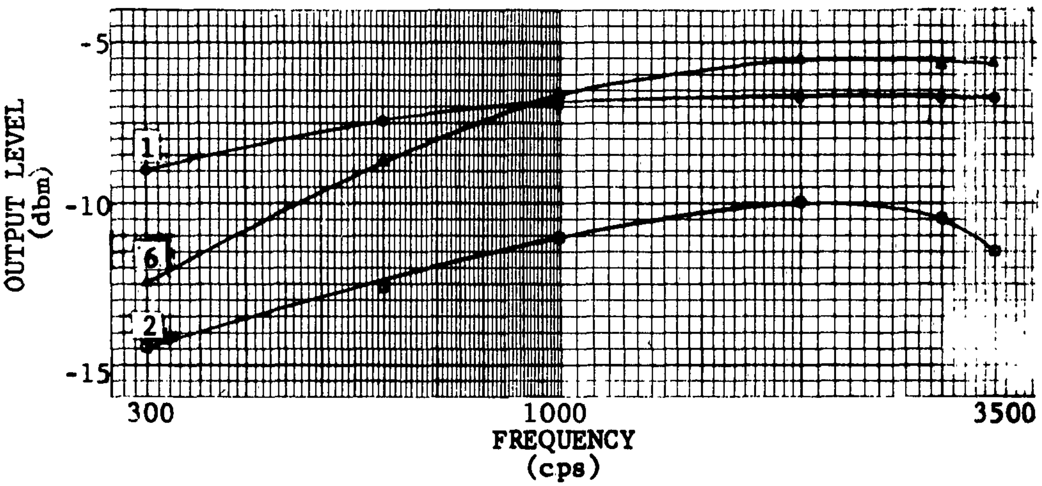


FIGURE B-179

SYSTEM FREQUENCY RESPONSE
WIRE ONLY
Configurations 1, 2 and 6
Input Level -4 dbm

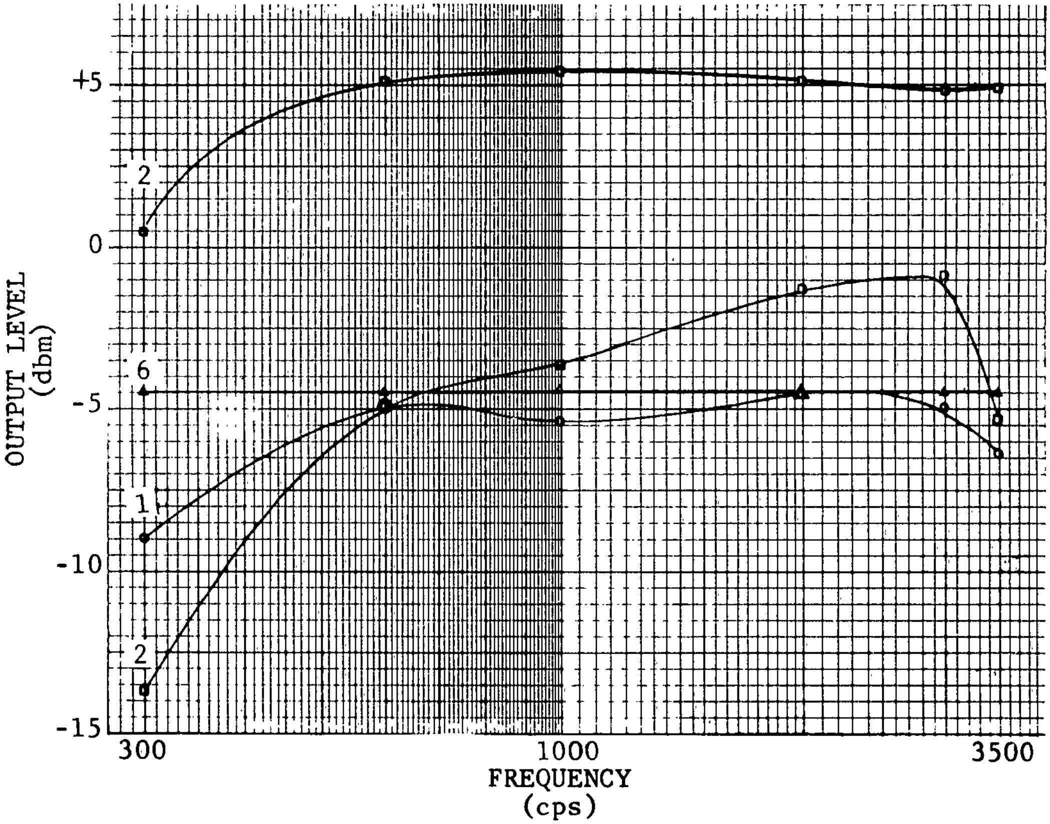


FIGURE B-180

SYSTEM FREQUENCY RESPONSE
WIRE CARRIER SYSTEM
Configurations 1, 2 and 6
Input Level -4 dbm

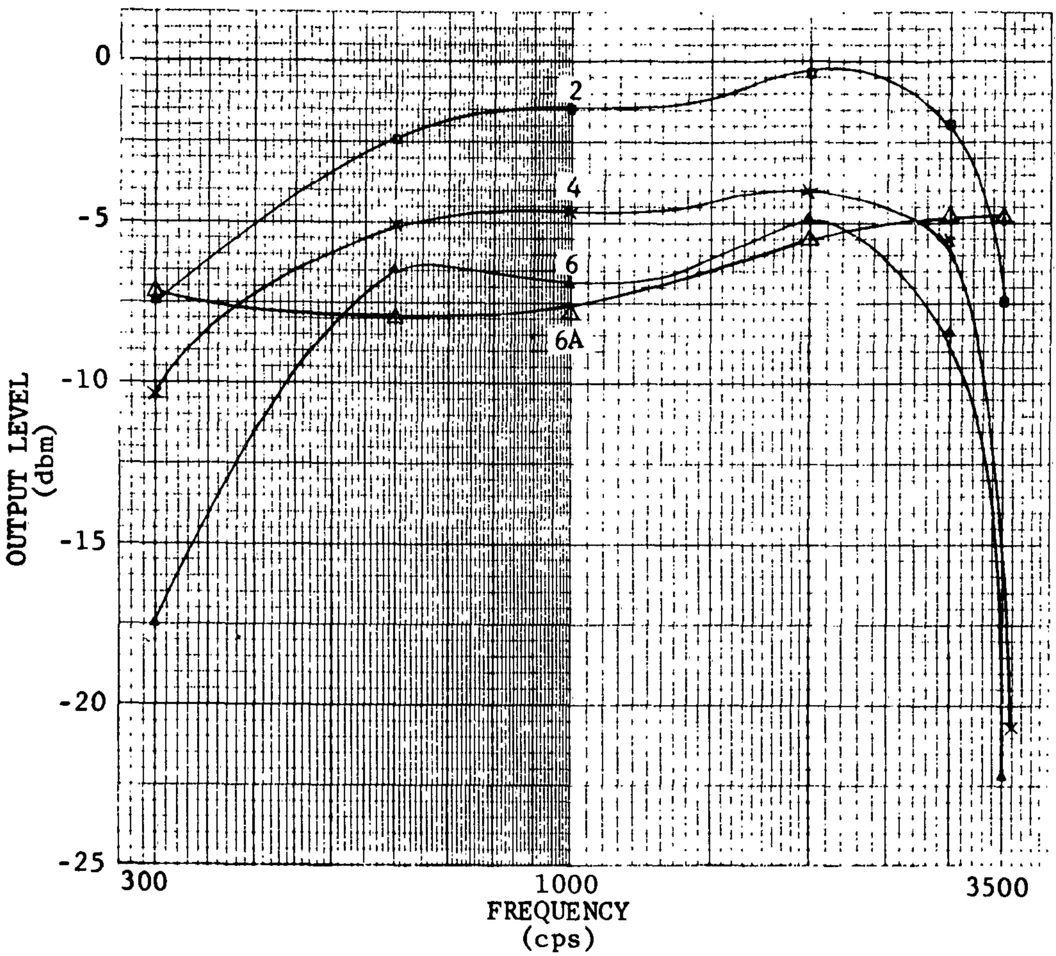


FIGURE B-181

SYSTEM FREQUENCY RESPONSE
RADIO CARRIER SYSTEM
Configurations 2, 4, 6 and 6A
Input Level -4 dbm

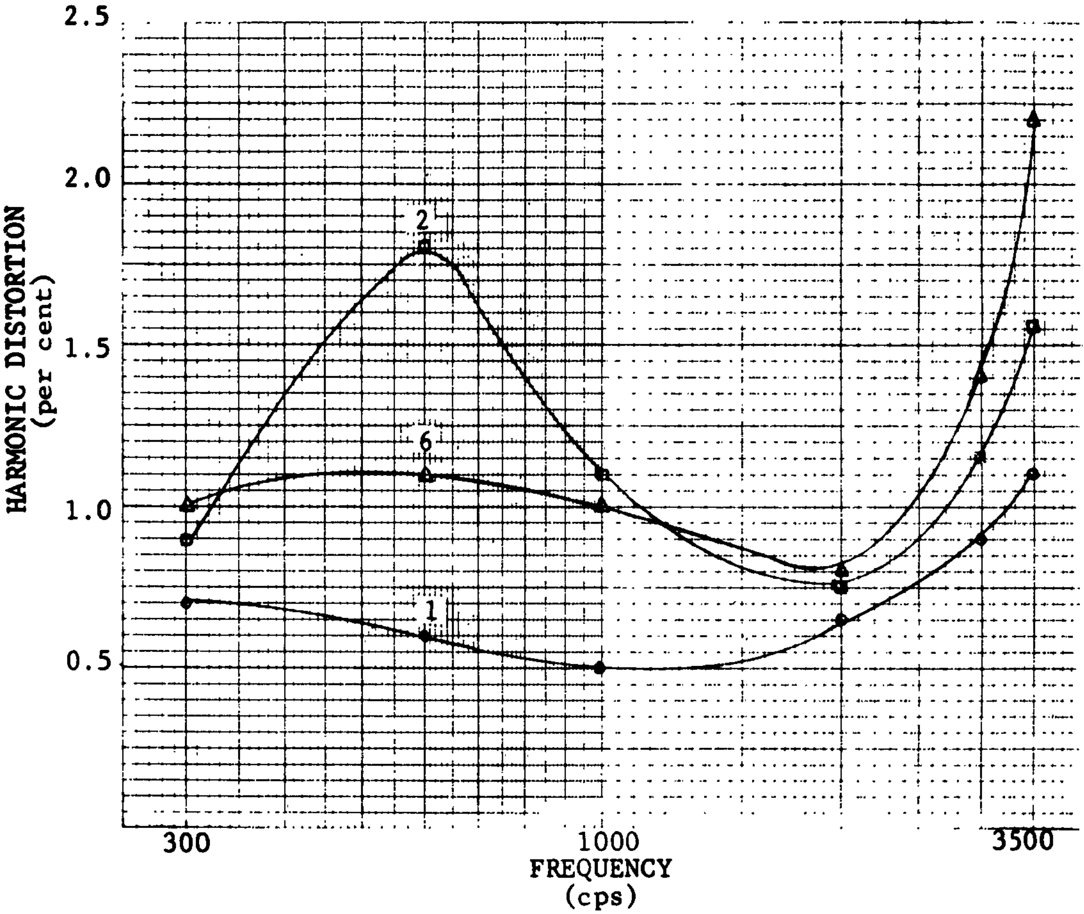


FIGURE B-182

SYSTEM HARMONIC DISTORTION
Wire Only
Configurations 1, 2 and 6
Input Level -4 dbm

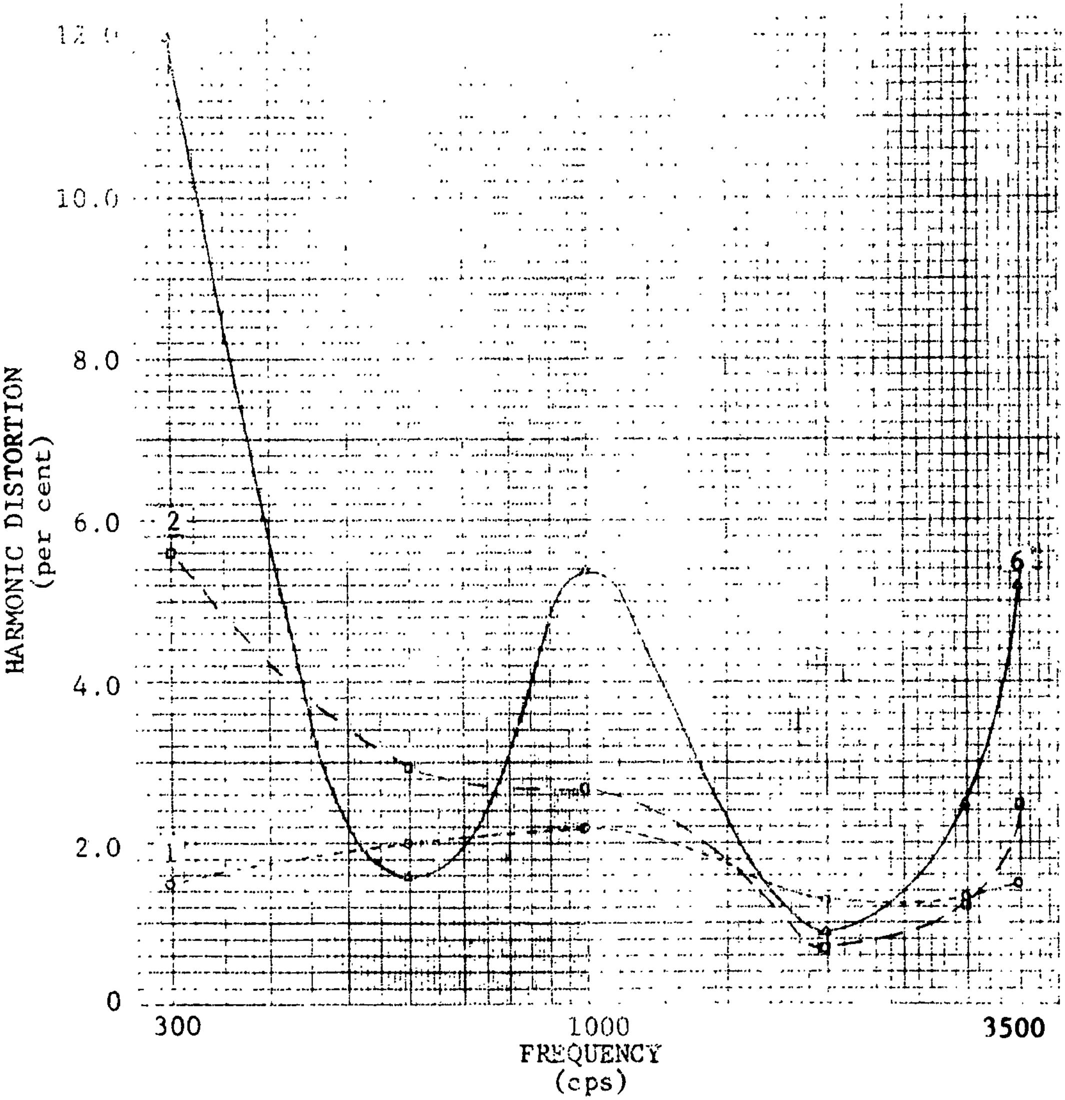


FIGURE B-183

SYSTEM HARMONIC DISTORTION
Wire Carrier System
Configurations 1, 2 and 6
Input Level -4 dbm

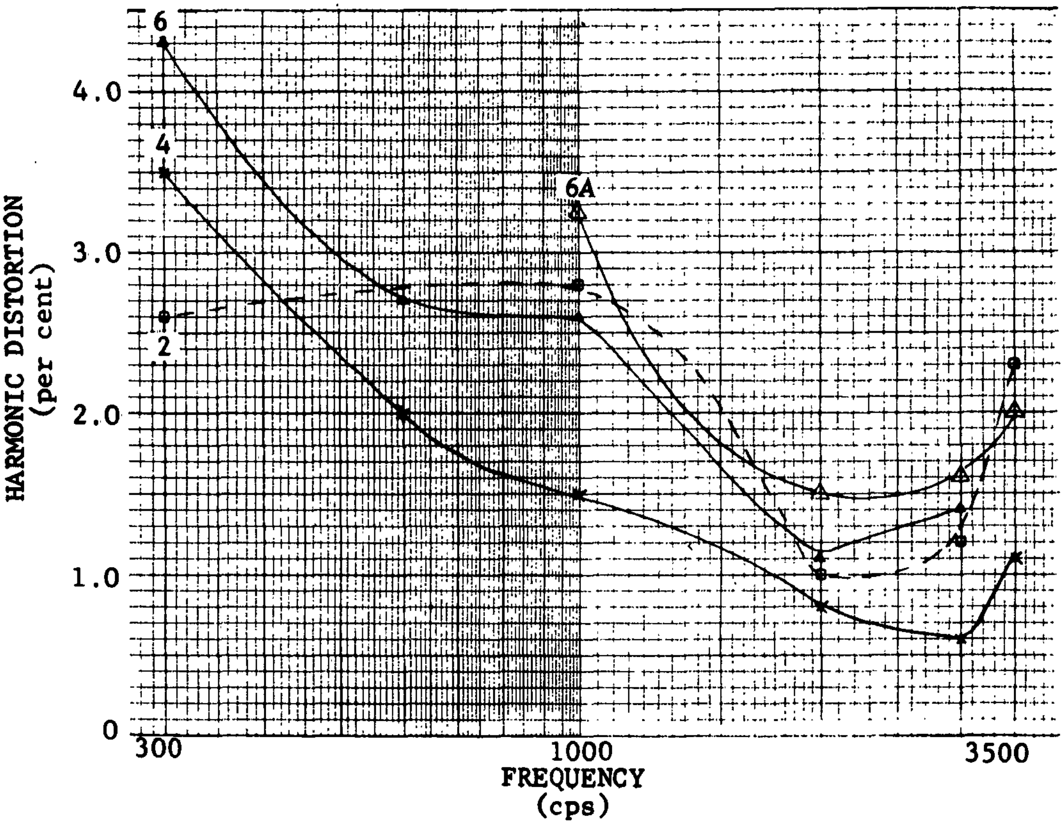


FIGURE B-184

SYSTEM HARMONIC DISTORTION
RADIO CARRIER SYSTEM
Configurations 2, 4, 6 and 6A

3.1.3.3 INTERMODULATION DISTORTION

Intermodulation distortion measurements were not taken on any of the system configurations due to the failure of the W.E. 4-A Wave Analyzer.

3.1.3.4 NOISE

Table B-63 tabulates the noise levels measured for configurations 1, 2, 4 and 6 over wire, wire carrier and radio carrier media. The table shows the noise buildup as the system becomes more complex. It also shows the radio paths to be noisier than the wire carrier paths.

3.1.3.5 SIGNAL TO NOISE

For a discussion of signal to noise, see Section 4.0.

3.1.3.6 OPERATIONAL RELIABILITY OF TANDEM CONFIGURATIONS

Attempts to perform reliability tests through the 6 system configurations proved to be difficult and time consuming due to the high maintenance requirements on the electronic switching centrals. The troubleshooting involved the removing of alarm conditions from the centrals, the release of hung up links, the change of highways, and other problems so that calls could be established. The problems resulted in down time, delays and incompleteness of testing. A total of 200 calls were attempted through system configuration 5 (Figure B-178) with 118 (59 per cent) successes. Many of the successful calls were made only after faulty circuits were corrected or busied out. In tracing the causes of keying failures, the AN/TTC-13 was found to be the most troublesome. The AN/TTC-15 and AN/TTC-12 created fewer problems and the AN/TTC-14 was trouble free in placing calls, although on two occasions AN/TTC-14 line links failed to release upon call termination. The majority of the system failures were traced to the route selector and link circuitry of the AN/TTC-12, 13 and 15.

3.2 COMPATIBILITY TESTS RESULTS

The following test results indicate the degree of compatibility of the automatic electronic switching equipments with the several currently operational equipments.

TABLE B-63

SYSTEM NOISE

TEST CONFIGURATION	TRUNKING MEDIUM	NOISE (dba)
1	Wire Only	24
1	Wire Carrier	25
1	Radio Carrier	---
2	Wire Only	22
2	Wire Carrier	24
2	Radio Carrier	29
4	Radio Carrier	35
6	Wire Only	30
6	Wire Carrier	31
6	Radio Carrier	37
6A	Radio Carrier	35

3.2.1 COMPATIBILITY WI FIELD WIRE

The capability of WF-16 (four conductor) and paralleled WD-1/TT (two conductor) field wire to serve as a trunking media between automatic electronic switching centrals was to be determined. The WD-1/TT was not tested due to the unavailability of necessary wire quantities during the testing program.

The basic characteristics of the WF-16 field wire are presented in Section 2.10 of this volume. No anomalies are observed in this data. It appears that normal line attenuation of the WF-16 will be the limiting factor when used to interconnect the electronic switching centrals.

The operational test results are presented in Table B-64.

In addition to these operational tests, five miles of WF-16 was used to interconnect the AN/TTC-14 and the AN/TTC-15 in system configuration number 1. The attenuation of the signal levels were down (10.5 db at 300 cps, 11 db at 1000 cps, 15 db at 3000 cps and 16 db at 3500 cps) from the levels obtained with short wire interconnections. The total harmonic distortion was under 1.6 per cent at all frequencies in the 300-3500 cps passband. The noise level measured 2.2 millivolts.

3.2.2 COMPATIBILITY WITH WIRE CARRIER SYSTEMS

The successful use of the AN/TCC-7 wire carrier and spiral four cable in the interoperational tests of Section 2.0 furnished ample proof of the compatibility of electronic centrals with this carrier system.

The data, particularly that on the complex system of Configuration 6, pointed out the necessity for precise alignment of the carrier terminals. During one test, improper alignment resulted in harmonic distortion which varied cyclically from 1 to 17 per cent at about a 3 second per cycle rate. During other tests the peculiar response curves of Figures B-180 and B-181 were obtained, with the data taken at intermediate points, supporting the theory that carrier misalignment was the cause.

Assuming proper alignment, it is estimated that many hundreds of miles of AN/TCC-7 wire carrier system could be used to interconnect electronic switching centrals.

TABLE B-64

OPERATIONAL COMPATIBILITY OF WF-16 FIELD WIRE WITH AUTOMATIC ELECTRONIC EQUIPMENTS

	TEST CONFIGURATION	MAXIMUM WIRE LENGTH USABLE	REMARKS
1.	AN/TCC-7 (WF-16) AN/TCC-7	7 Miles	
2.	AN/TTC-12-AN/TCC-7 (WF-16) AN/TCC-7-AN/TTC-12	5	
3.	AN/TTC-14-AN/TCC-7 (WF-16) AN/TCC-7-AN/TTC-14	4	
4.	TA-341 (WF-16) TA-376-AN/TTC-12	22	Signalling - Good Voice - Poor but readable
5.	SB-22-TA-376 (WF-16) AN/TTC-14	7 (10)	10 mile figure obtained with TA-344 repeater
6.	SB-22-TA-376 (WF-16) AN/TTC-12	1 (4)	4 mile figure obtained with TA-344 repeater
7.	SB-86-TA-376 (WF-16) AN/TTC-14	9 (12)	12 mile figure obtained with TA-344 repeater
8.	SB-86-TA-376 (WF-16) AN/TTC-12	1 (4)	4 mile figure obtained with TA-344 repeater
9.	TA-341 (WF-16) TA-341 (Pt to Pt Wire Mode)	Over 22	Test lines limited to 22 miles
10.	TA-341 (WF-16) TA-341 (Pt to Pt Radio Mode)	11 (14)	14 mile figure obtained with TA-344 repeater
11.	TA-341 (WF-16) AN/TTC-12	9 (12)(13)	9 miles obtained from TA-341 to AN/TTC-12; 12 miles obtained from AN/TTC-12 to TA-341; 13 miles obtained both ways with TA-344 repeaters
12.	TA-341 (WF-16) AN/TTC-14	11 (14)	14 mile figure obtained with TA-344 repeater

3.2.3 COMPATIBILITY WITH RADIO CARRIER SYSTEMS

The successful use of the AN/MRC-69 (AN/TRC-24) radio carrier system during the interoperational tests of Section 2.0 furnished substantial evidence of the compatibility of the electronic centrals with radio carrier systems. The data obtained on the radio carrier tests pointed out the necessity for precise alignment of radio equipment and carrier terminals.

These tests were used to determine the circuit quality necessary for interconnection of electronic switching centrals. Signal to noise figures were determined on the simple configuration (Configuration 2 of Figure B-178). Tests on the more complex systems, such as Configurations 4, 5, 6 and 6A proved the validity of these signal to noise results. The signal to noise ratios found necessary for proper signalling based on signalling tones of -18 dbm amplitude was dependent upon the signal to noise figure on the individual equipments. Further discussion of this topic may be found in Section 4.0.

3.2.4 COMPATIBILITY WITH TROPOSPHERIC SCATTER RADIO CARRIER SYSTEM

3.2.4.1 The purpose of this test was to evaluate the ability of the automatic electronic telephone switching equipments to signal and communicate over tropospheric scatter radio trunks. The radio set used in these tests was the AN/MRC-80. Early scheduling of these tests was required due to limited availability of the scatter equipments. This precluded the test including the AN/TTC-15 tandem central. Thus, tests were performed with only AN/TTC-12, AN/TTC-13 and AN/TTC-14 equipments. Access to the radio circuit was through the AN/TCC-7, 12 channel telephone carrier terminal equipment.

3.2.4.2 The radio terminals were located approximately 102 miles apart, one near Picacho, Arizona and the other at Blacktail Canyon on Fort Huachuca. The power output of each terminal was 1000 watts except during special tests made at reduced power. Two receivers at each site, with appropriate antennae provided dual diversity reception. The radio equipment was operated by the Radio Division of the Signal Communications Department. All information concerning the radio path, recordings of median signal level, etc. was supplied by that division.

3.2.4.3 The automatic switching equipments located at the Picacho terminal were the AN/TTC-12 and the AN/TTC-14. Located at Blacktail Canyon were the AN/TTC-12, AN/TTC-14 and the AN/TTC-13. The twelve channels of the AN/TCC-7 connected the automatic switching equipment to the AN/MRC-80 radio set. Figure B-185 shows the circuit for the test of the tropospheric system.

3.2.4.4 The compatibility of the equipments was evaluated on the basis of signalling reliability and speech intelligibility over 19 different equipment configurations. Tests were made over a 5 day period. Nocturnal and diurnal variations were observed, as well as variations due to changes of transmitter power. The transverse and elevation profiles of the radio path are shown in Figures B-186 and B-187.

A series of 25 tests were performed to evaluate the ability of the automatic electronic switching centrals to communicate over the AN/MRC-80 radio link. The results of each of the 25 tests are detailed in Table B-65. Detailed information obtained for tests 20 through 25 at various transmitter power outputs are tabulated in Table B-66.

Median AN/MRC-80 receiver input levels (60 second samples) were recorded for the receivers located at Blacktail Canyon and at Picacho for the five day period. A typical plot of the median receiver signal levels obtained is shown in Figure B-188. The noise levels measured at the output of the AN/TCC-7 carrier are shown in Figure B-189.

Analysis of the data showed a satisfactory number of successful keyings through the several test configurations as long as the median signal level held near or above -100 dbm. When the signal level fell below -100 dbm, the percentage of keying successes dropped noticeably. Normally, noise measured in the region of 30 to 60 dba and caused little trouble. When noise exceeded 60 dba, keying became unreliable.

The data taken at reduced transmitter power was about as expected. The variations in signal strength (transmitted power) reflected directly in keying successes. The noise level held at about 65 dba for all tests but number 20, which was at 47 dba. This noise reduction accounts for the higher keying success, even though transmitter power was lower.

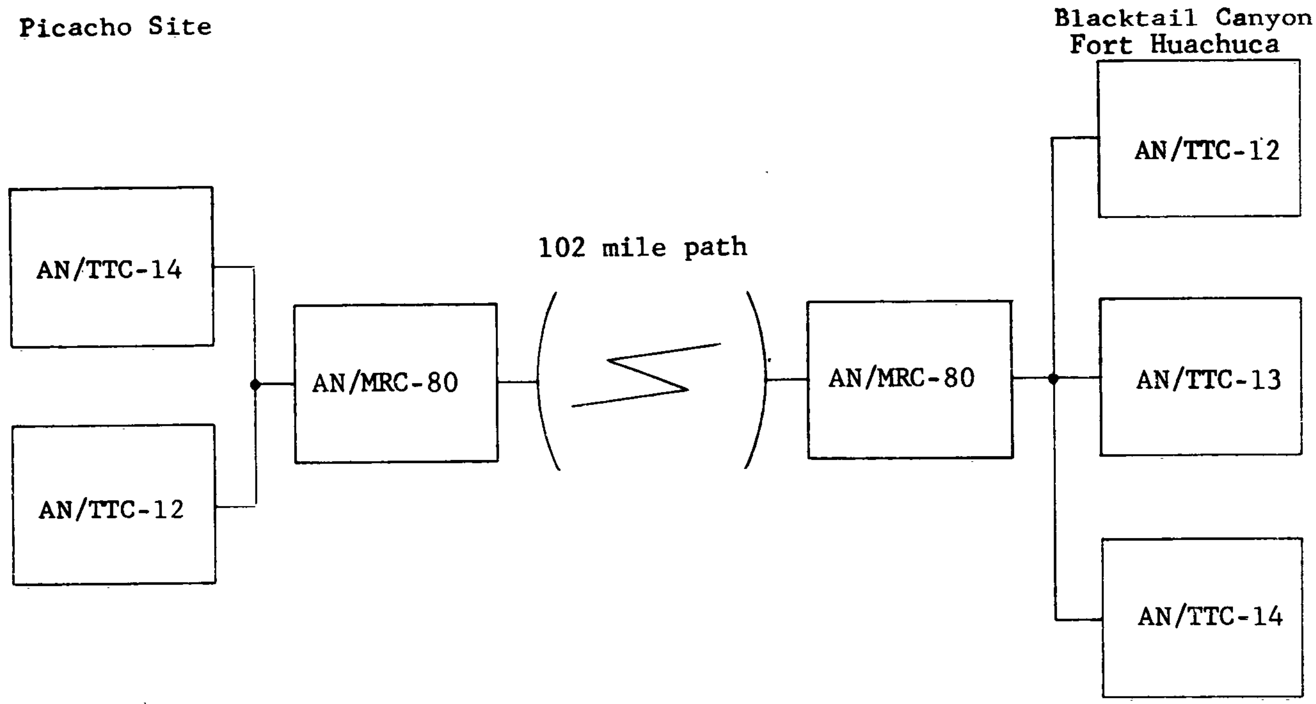


FIGURE B-185

TROPOSPHERIC SCATTER TEST CONFIGURATION

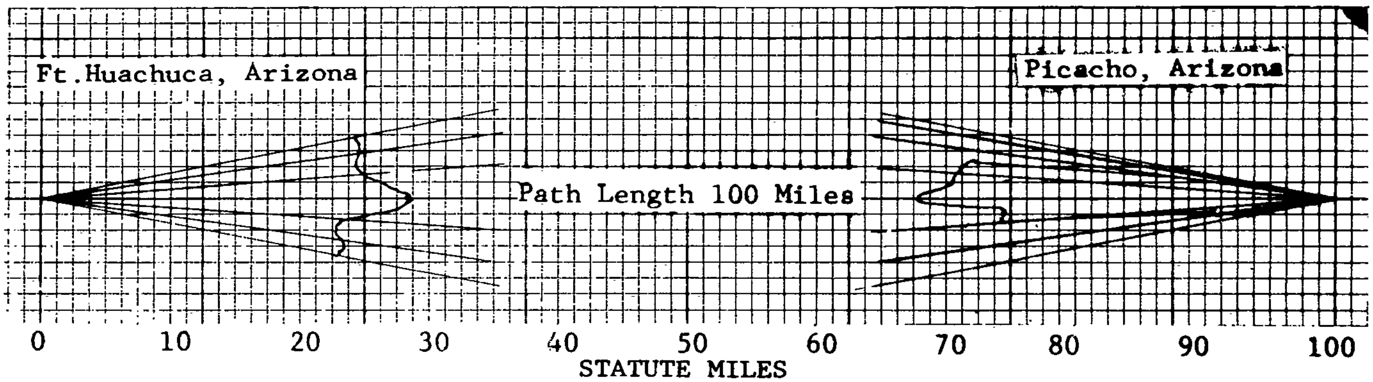


FIGURE B-186

TRANSVERSE PROFILE
TROPOSPHERIC SCATTER TRANSMISSION PATH
FORT HUACHUCA TO PICACHO, ARIZONA

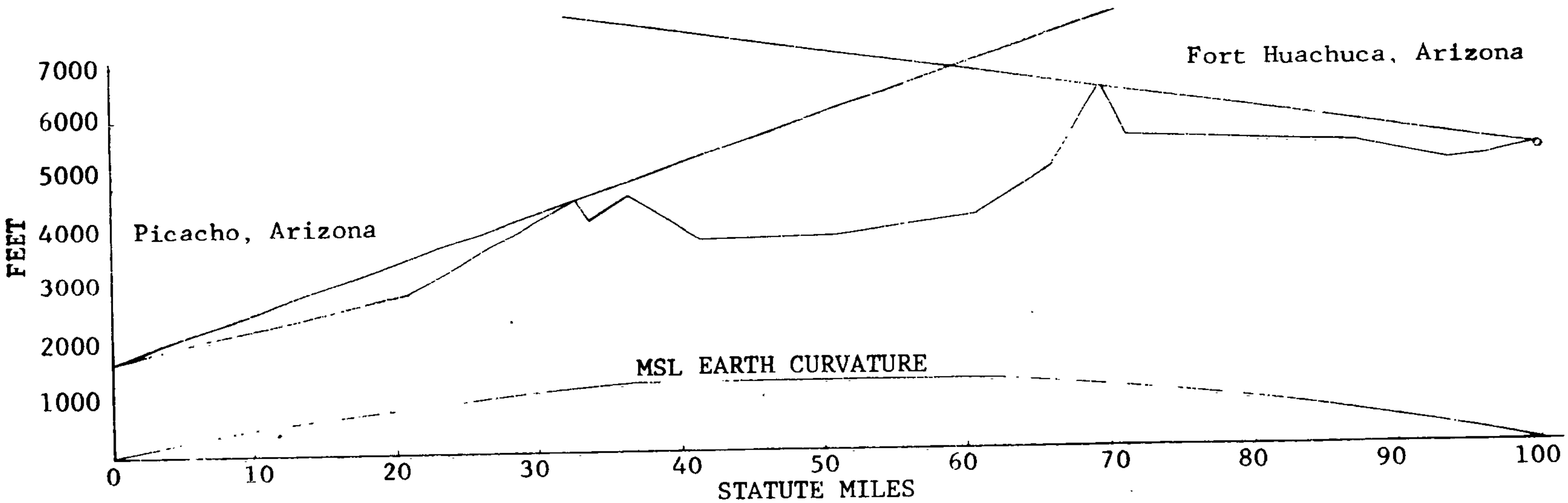


FIGURE B-187

RADIO TRANSMISSION PATH PROFILE
PROFILE ASSUMES 4/3 EARTH RADIUS

TABLE B-65

TEST RESULTS FOR AN/MRC-80 COMPATIBILITY TEST

TEST NO.	EQUIPMENT CONFIGURATION	NO. OF CALLS	PER CENT SUCCESSES
1	12B(R)12A	23	100
2	12B(R)14A	24	100
3	14B(R)14A	69	100
4	14B-12B(R)13A-12A	51	94
5	14B-12A(R)13A-14A	69	97
6	12B(R)-13A-12A	40	87.5
7	14B(R)13A-14A	74	97.5
8	12A(R)12B	81	91.5
9	14A(R)12B	68	97
10	14A(R)14B	102	99
11	12A-13A(R)14B	67	94
12	12A-13A(R)12B-14B	107	90.5
13	14A-13A(R)12B-14B	107	78.5
14	14B(R)14A(R)14B	4	100
15	14B(R)12A(R)12B	2	100
16	12B(R)13A(R)12B(R)14A	4	50
17	14B(R)12A-13A-13A-12A	3	66.6
18	14B-12B(R)13A-13A(R)14B	2	50
19	14B-12B(R)13A-13A-12B	4	50
20	Same as Test #8-13 100W	66	38
21	Same as Test #8-13 200W	68	31
22	Same as Test #8-11 300W	50	30
23	Same as Test #8-13 400W	80	54
24	Same as Test #8-13 500W	98	63.5
25	Same as Test #8-13 700W	25	92

A - Ft. Huachuca Terminal
B - Picacho Terminal
R - Radio Relay Link (Tropo Path)
12 - AN/TTC-12
13 - AN/TTC-13
14 - AN/TTC-14

TABLE B-66

TESTS PERFORMED AT BLACKTAIL CANYON
AT VARIOUS TRANSMITTER POWER OUTPUTS

(Reference Table B-65)

TEST NO.	POWER OUTPUT (Watts)	EQUIPMENT CONFIGURATION	NO. OF CALLS	PER CENT SUCCESSES
20	100	8	9	55
20	100	9	12	42
20	100	10	7	0
20	100	11	6	83
20	100	12	14	29
21	200	8	5	0
21	200	9	29	17
21	200	10	5	100
21	200	11	11	45
21	200	12	5	20
21	200	13	13	38
22	300	8	11	45
22	300	9	19	0
22	300	10	8	62
22	300	11	12	42
23	400	8	10	50
23	400	9	22	18
23	400	10	14	78
23	400	11	8	100
23	400	12	10	50
23	400	13	16	63
24	500	8	12	83
24	500	9	18	55
24	500	10	26	77
24	500	11	12	83
24	500	12	17	41
24	500	13	13	38
25	700	8	5	80
25	700	9	5	100
25	700	10	3	100
25	700	11	3	100
25	700	12	3	100
25	700	13	6	83

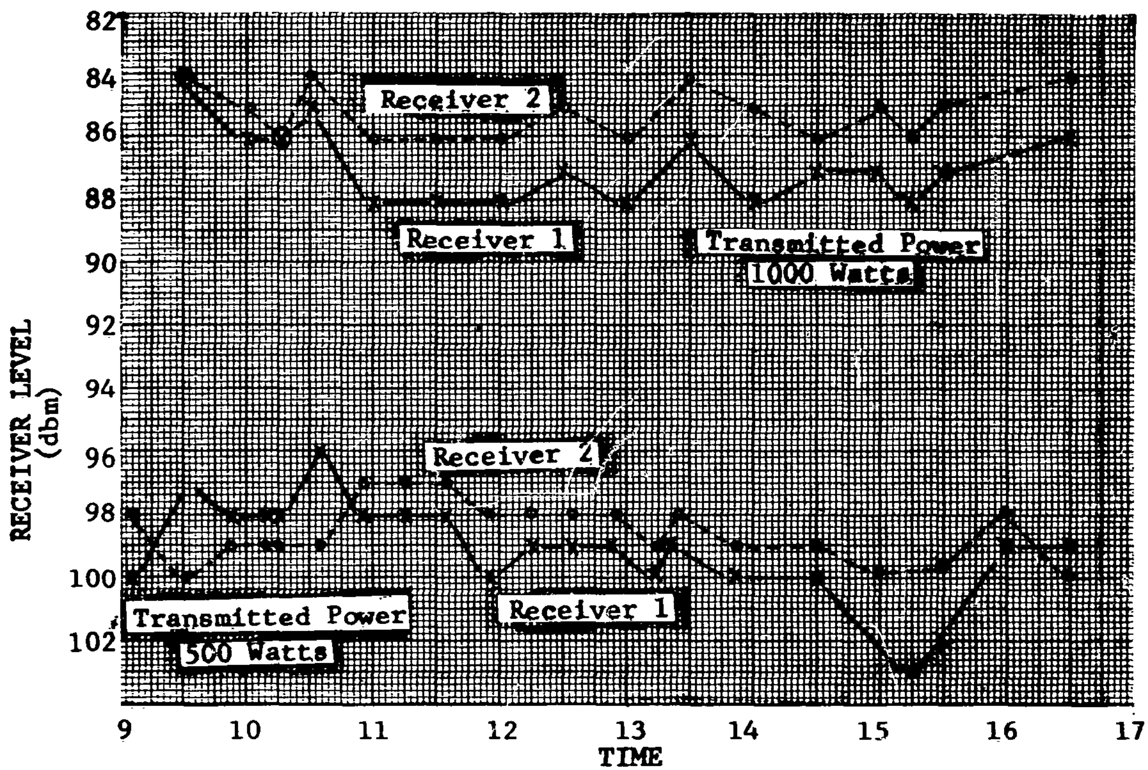


FIGURE B-188

MEDIAN SIGNAL LEVEL (60 Second Samples)
AN/MRC-80

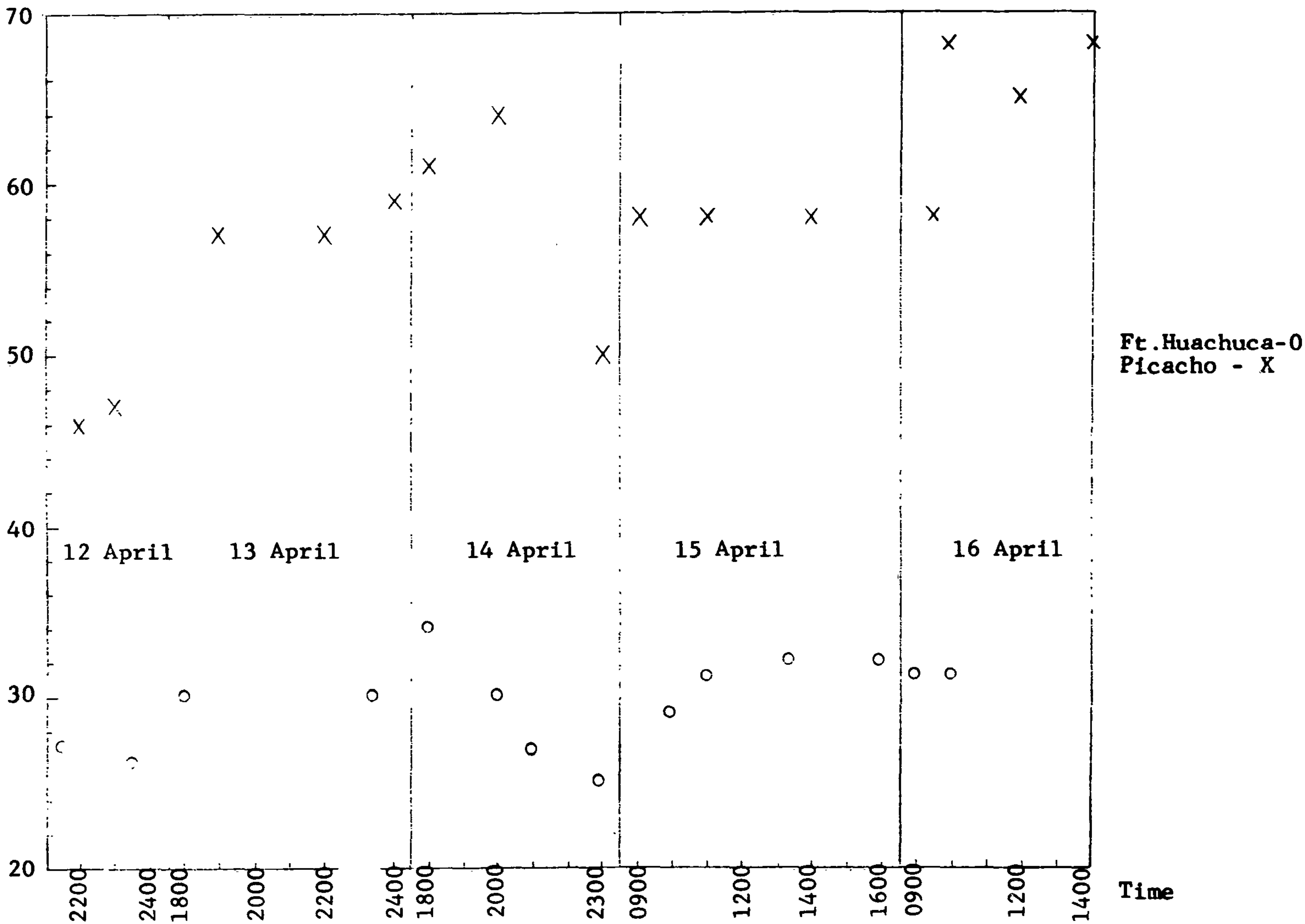


FIGURE B-189

NOISE ON RADIO CIRCUIT (Output of AN/TCC-7 Carrier)

3.2.5 COMPATIBILITY WITH MANUAL SWITCHBOARDS

Several of the system configurations of the interoperational tests were extended to include checks with manual switchboards and the new semiautomatic SB-1191. Also the WF-16 compatibility tests of Section 3.2.1 included tests of manual switchboards. All data indicated satisfactory operation utilizing the TA-376 converter and necessary hybrids in conjunction with the SB-22 and SB-86 switchboards. Numerous calls were placed to and from both switchboards, and teletype and facsimile were successfully transmitted through the SB-86 to the electronic switching centrals. The SB-1191 was found to perform satisfactorily in the system tested (Configuration 5).

3.2.6 COMPATIBILITY WITH TELETYPE, FACSIMILE AND DATA SYSTEMS

Teletype and/or facsimile tests were run over several of the interoperational test system configurations of Section 2.0, over the tropospheric scatter tests of Section 3.2.4 and over the manual to electronic switching central tests of Section 3.2.5. 60 and/or 100 word per minute teletype was successfully passed over all of the tested configurations. Facsimile was successfully transmitted over Configurations 5, 6 and 6A. The reproduction quality over the system configuration compared favorably with that obtained on a control monitor, set up adjacent to the transmitting equipment. The quality was determined by analysis of results using a Facsimile Test Chart, prepared by the Institute of Radio Engineers Technical Committee on Facsimile.

Tests of data system compatibility with the electronic switching centrals were rescheduled to be performed during later operational tests, conducted by the USAEPG.

4.0 ENGINEERING COMMENTS AND DISCUSSION

In addition to the direct test results reported on in Sections 2.0 and 3.0 of this volume, a number of observations were made during the conduct of the evaluation. The following paragraphs are included to cover these unassigned areas. The data substantiating some of the statements, and the depth of research into solutions to the various problems, was limited by time and the scope of the contract. The discussion is presented to point out problem areas which should be further explored before initiating the design and fabrication of future generation equipments. Comments and discussion on individual equipments are treated first, followed by system considerations.

4.1 EQUIPMENT OBSERVATIONS

4.1.1 AN/TTC-12, AN/TTC-13, AND AN/TTC-15 CENTRALS

(1) Maintenance - The AN/TTC-12, 13 and 15 switching centrals were found to require excessive maintenance. The periodic scheduled maintenance was not sufficient to keep the centrals in reliable operating condition. When moved physically from site to site, the centrals required extensive maintenance before commencing operation.

(2) Power Supply - The battery power supply provided approximately one hour of emergency operation after failure of a primary power source. When the charge on the batteries was allowed to fall below a critical level, sufficient battery power was not available to activate the emergency changeover relay upon restoration of primary power. In this instance, complete replacement of batteries was necessary to restore normal operation. Activation of the changeover relay is presently accomplished by the battery voltage and is extremely voltage sensitive. A circuit change is suggested to permit activation of this relay by the 110 volt a-c primary source which would restore operation of the charger immediately upon reconnecting the primary power.

The battery chargers appear to be underrated. They were found to be incapable of maintaining normal operation of the central while simultaneously recharging low batteries. It was necessary to either curtail operation of the central for a period of approximately 6 hours while recharging, or to replace the batteries.

(3) Cooling - It was observed that ambient shelter temperatures above 115°F caused erratic operation of the centrals. No quantitative data on the temperature stability was recorded.

The refrigerated cooling air should be rerouted so as to cool all equipment drawers. Or preferably, the design should utilize higher temperature components, with cooling provided by exhaust fans drawing ambient shelter air through the drawers.

(4) Surge Protection - No tests were run to check the operation of the line lightning arrestors. It can be safely assumed that the arrestors, being of a standard type, will function properly within design range. However, it is felt that the arrestors would afford better protection to the complete switching central if they were situated on the field side of the MDF (main distribution frame), instead of inside the shelter on the patching MDF.

4.1.2 AN/TTC-14 CENTRAL

The only problem observed on the AN/TTC-14 switching central was one of maintenance, following a physical relocation. Once made operational at a new site, the equipment was reliable.

4.1.3 TA-341/PT TELEPHONE SET

Several problems or potential problems were encountered with the TA-341 telephone set. These were as follows:

(1) The telephone set, and particularly the coiled cord and handset, is susceptible to pickup of a-c fields. Operation of the telephone in the vicinity of the battery charger of the AN/TTC-12 (fairly common practice for the Wire Chief), resulted in substantial a-c power pickup.

(2) When several telephone sets are colocated, it is difficult to determine which telephone is being called. A visual indicator might be helpful.

(3) Undesired release of established calls can occur when telephones are operating in close proximity. The release tone returned to the speaker of one handset can be picked up audibly by the transmitter of the adjacent handset and can cause release of this circuit.

(4) The sidetone present on the TA-341 during the keying process presents a temptation to "play" the keyboard for its musical quality. A solution to this problem could be the distorting or subduing of the sidetone signals.

4.1.4 SB-1191 SWITCHBOARD

(1) The SB-1191 returns only one ringback tone to the system. Subscribers, accustomed to the intermittent ringback received from the automatic switching centrals, might believe erroneously that the call has been lost.

(2) The battery drain on the SB-1191 was found to be excessive. During the tests, complete replacement of the battery complement (30 each BA-30 Type D cells) was necessary once per 8 hour day. This did not agree with the Handbook which stated 7 day operation from one set of batteries.

4.2 SYSTEM OBSERVATIONS

4.2.1 TWO TONE DIALING SYSTEM

The two tone system of dialing was found to be reliable. However, the timing and coordination of keying requires considerable experience on the part of the subscriber. The observations made upon dialing through tandem configurations of the electronic switching centrals are as follows:

(1) When dialing through a tandem configuration the spacing between tone bursts is critical. The switching centrals will time out if the dialing sequence is interrupted or if the subscriber is dialing too slowly. Exasperated subscribers would use the operator for placing the call.

(2) The centrals in a system configuration may or may not return a dial tone to the subscriber. This can cause confusion on the part of the subscriber as to how his call is progressing.

(3) When rerouting in an AN/TTC-15 tandem configuration the time delay in the return of a dial tone is approximately 6 seconds. This extended delay is disturbing to an inexperienced subscriber.

4.2.2 TRUNKING CONSIDERATIONS

At several points in the presentation of detailed system test results (Section 3.0) mention is made of the necessity to precisely align the carrier equipment. The general statement can be made that the standard alignment procedure for the carrier equipment is not proper for use with the automatic switching equipments.

The limiting which occurs in the electronic centrals (to signals above -4 dbm) results in degradation of system performance if the standard (+1 dbm) level from the carrier terminal is inserted into the switching centrals. When transmitting facsimile, this limiting action destroyed the tonal quality of the copy by compressing the gray scales toward the white end.

Procedures were developed for alignment of the carrier equipments based on a no loss - no gain loop measurement, with gains set for -4 dbm output to the switching centrals. This procedure is not consistent with present field army usage so a standard procedure must be developed.

The same general philosophy pertains as well to the radio carrier equipments when used with the electronic switching equipment. Signal level to the AN/TCC-7 carrier terminals from the radio equipment must be stable and of the proper level.

Both radio and carrier terminal equipments must exhibit uniform subcarrier channel characteristics to prevent unusual response or distortion within specific channels.

4.2.3 SIGNAL TO NOISE CONSIDERATIONS

Reliable signalling can be made through tandem arrangements of automatic electronic telephone switching centrals providing that a signal to noise ratio can be maintained which will assure seizure, dialing and release of the centrals at this signalling level.

A marginal signal to noise figure can be predicted for any system configuration. If a ratio can be maintained above the marginal ratio, successful signalling through the configuration can be assured.

Under marginal conditions due to noise, random seizure and false dialing were observed to occur. In most cases of random seizure the broadly sensitive seize detectors would actuate but the registers, having narrow sensitivity bandpass and voice guard capabilities, would reject the noise simulated seize tone.

During the period of time following the random seizure of the seize detector and before the register rejected the seizure as improper, any legitimate 1700 cps seize signal appearing at the detector would be rejected and a busy signal sent to the calling source.

False dialing occurs when noise bursts interrupt a combination of digit signalling tones. The interruptions are interpreted by the register as a tone combination being repeated. In keying through a long distance central an entire keying sequency can be simulated. Therefore, when operating over trunks under marginal signal to noise conditions, false dialing frequently occurs, resulting in random rerouting.

In multiple trunk calls, a called central may be seized, but acknowledgement of the call never received at the controlling central due to build up of noise level as it progresses from central to central. In the calling to called direction the signal is regenerated at each central, thereby eliminating noise build up. When the called local board is seized, however, an acknowledge signal must be returned over non-regenerating trunk lines. The noise on the signal increases as it passes over each additional trunk and the signal to noise ratio is thereby degraded. Marginal or submarginal conditions can be created in this manner and the controlling central may never receive acknowledgment of the seizure. This situation is aggravated by the low (-18 dbm) signalling level.

Under marginal conditions if a voice circuit is established it is generally a good one, the transmission power now being -4 dbm. Marginal signal to noise conditions should never exist in the transmission of teletype or facsimile because of the -4 dbm signalling level.

Sufficient information has been obtained in the testing program to enable the engineering of communication circuits with the automatic switching centrals using wire, wire carrier or radio transmission media. Minimum operating conditions under which any particular configuration of equipments will operate have been established.

The information which is most critical in determining whether any particular communication path can be established is the amount of noise present at or below the signalling level of -18 dbm. It has been ascertained that once the call is established the noise present at the transmitted power level of -4 dbm has little effect upon communication reliability. The establishment of a call through a system configuration consisting of various centrals is dependent upon the seize signal to noise ratio which must be exceeded to properly seize each central in the system.

Figure B-190 shows the signal to noise ratios observed on each of the detector circuits in the electronic switching centrals for a signalling level of -18 dbm. For a system including at least one of each of the centrals, in Figure B-190, it may be seen that the signal to noise ratio, to assure seizure of the board, must be maintained at a level no lower than 1.25, the highest ratio appearing in the system. This fact was observed in detail in testing Configuration 2 and was verified by checks on Configurations 5 and 6.

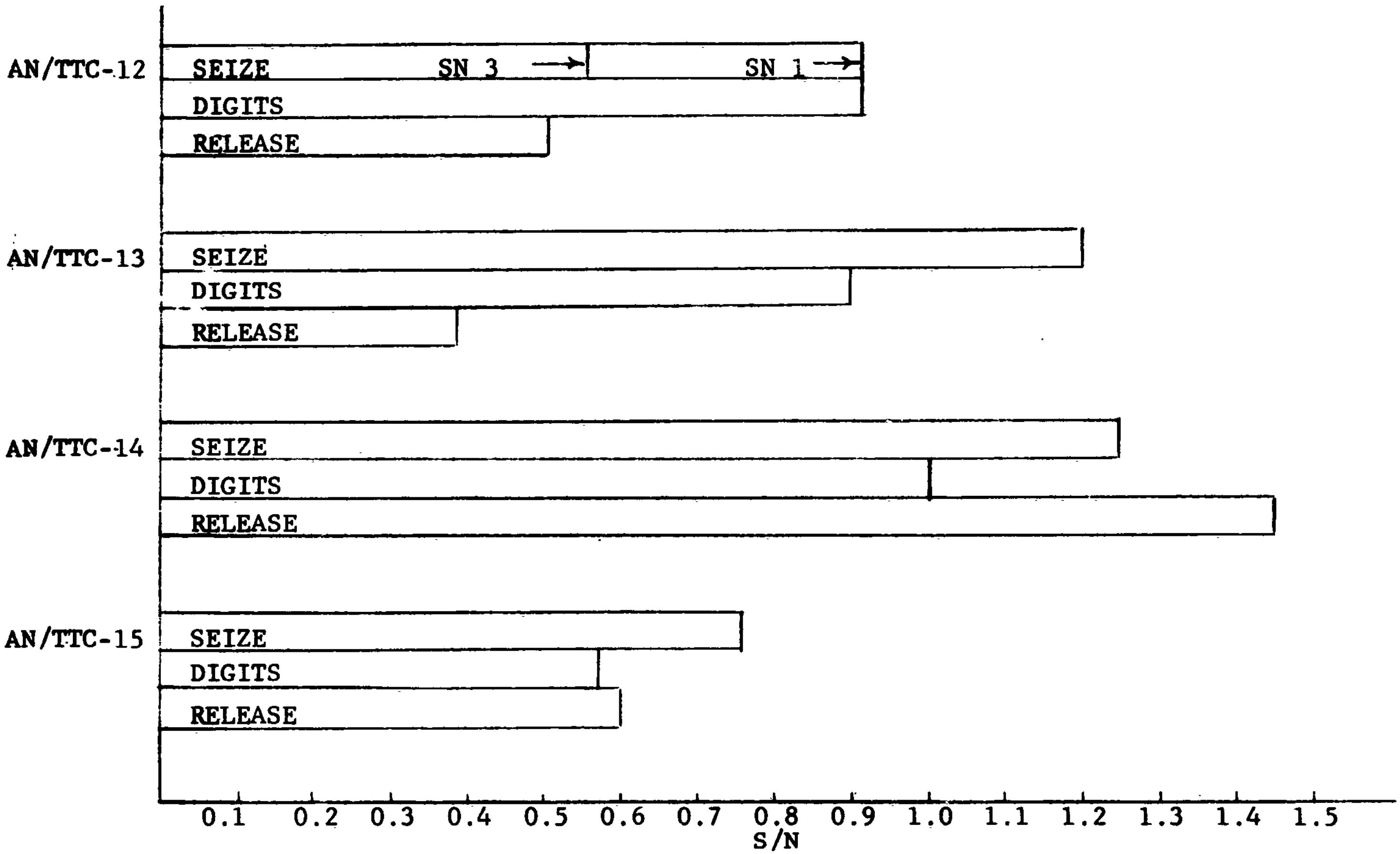


FIGURE B-190

DETECTOR SIGNAL TO NOISE RATIOS
(Required to assure reliable signalling)

Once the centrals in a system configuration have been seized, the signal to noise ratio present determines the dialing reliability. The signal to noise ratio also determines the successful release of calls. If the ratio is degraded below reliable operating levels then calls may never be released by the release tone.

The signal to noise ratios for -18 dbm signal power which must be exceeded to assure successful dialing and release for each of the centrals tested are shown in Figure B-190.

Seizure, dialing and release may be made more reliable by increasing the signalling power above -18 dbm thereby raising the signal to noise ratio. However, the noise levels experienced within typical system configurations will continue to produce random seizures and false dialing, because of the extreme sensitivity of the detector circuits. Decreasing the detector sensitivities would in effect bring the detector response above the region of noise interference. It is recommended, therefore, that in developing future generation equipments, the above philosophy be considered.

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